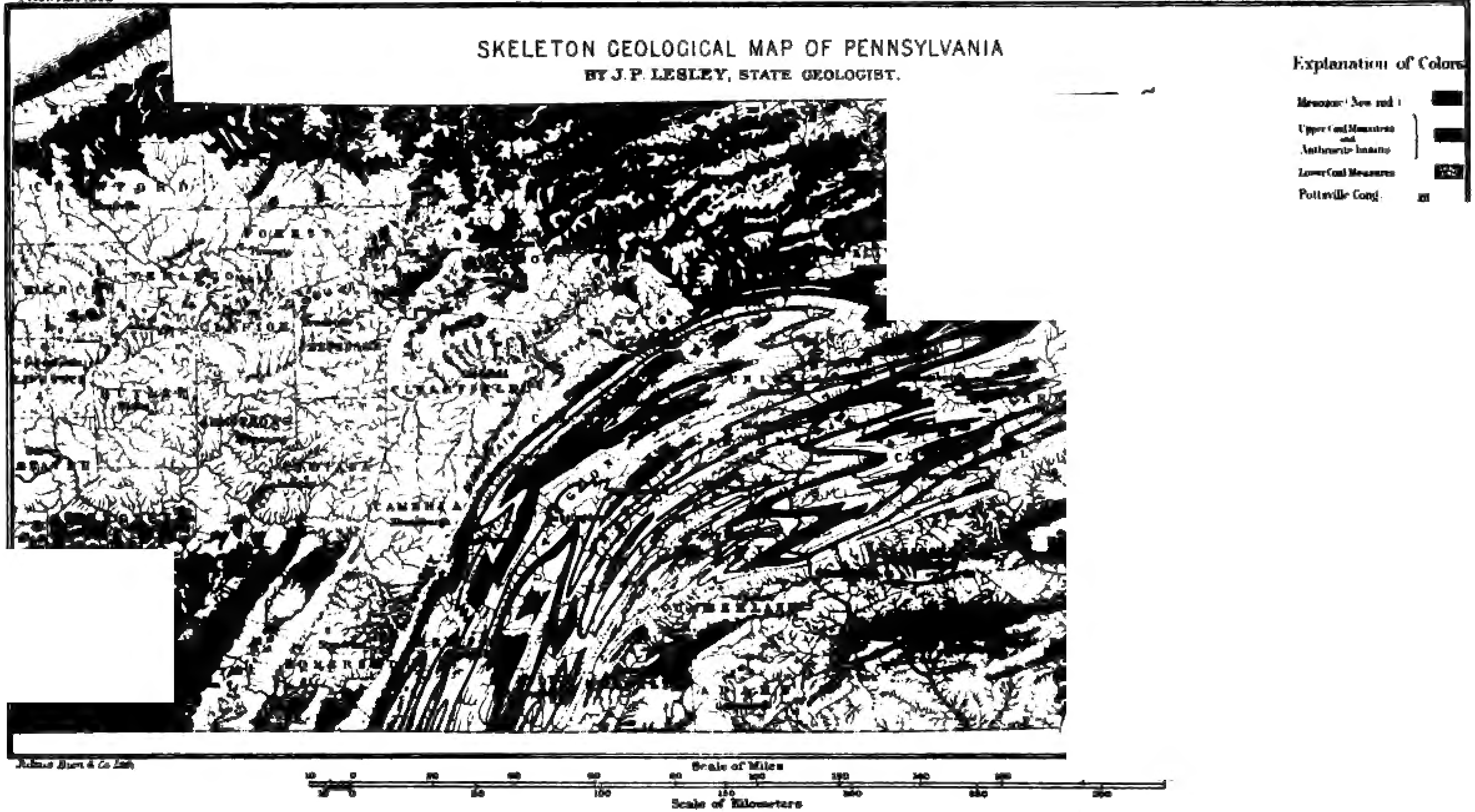
SKELETON GEOLOGICAL MAP OF PENNSYLVANIA

BY J. P. LESLEY, STATE GEOLOGIST.



Julius Bien & Co. Lith.

ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY

OF

PENNSYLVANIA. Geological survey (2d, 1874-1890)

FOR

1885.

By the STATE GEOLOGIST.

THE REPORT CONTAINS 5 FOLDED PLATES, 13 PAGE PLATES, AND 51 PAGE AND TEXT CUTS, AND IS ACCOMPANIED BY AN ATLAS OF 8 SHEETS OF MAPS AND SECTIONS.

HARRISBURG:
PUBLISHED BY THE BOARD OF COMMISSIONERS
FOR THE GEOLOGICAL SURVEY.
1886.

) year 1886, according

ological Survey,
m, at

BOARD OF COMMISSIONERS.

His Excellency, ROBERT E. PATTISON, *Governor*
and *ex-officio* President of the Board, Harrisburg.

ARIO PARDEE, ... Hazleton.
WILLIAM A. INGHAM, ... Philadelphia.
HENRY S. ECKERT, ... Reading.
HENRY MCCORMICK, ... Harrisburg.
SAMUEL Q. BROWN, ... Pleasantville.
CHARLES A. MINER, ... Wilkes Barre.
JOSEPH WILLCOX, ... Media.
LOUIS W. HALL, ... Harrisburg.
CHARLES H. NOYES, ... Warren.
JACOB TURNEY, ... Greensburg.

SECRETARY OF THE BOARD.

WILLIAM A. INGHAM, ... Philadelphia.

STATE GEOLOGIST.

PETER LESLEY, ... Philadelphia.

ASSISTANTS, 1885.

CHARLES A. ASHBURNER, Geologist in Charge of the Anthracite-Region and of the general field and executive work of the Survey.

JOHN F. CARLL, Assistant Geologist in the Oil and Gas-Regions.

E. V. D'INVILLIERS, Assistant Geologist in the Pittsburgh Coal-Region and the Great Valley.

A. E. LEHMAN, Ass't Geologist and Topographer, South Mountain Survey.

FRANK A. HILL, Assistant geologist, O. B. HARDEN, Assistant, GEORGE M. LEHMAN, Assistant, A. D. W. SMITH, Aid,	Anthracite-Region.
E. B. HARDEN, Topographer, BAIRD HALBERSTADT, Aid, J. ADACHI, Draughtsman, H. F. ALBRIGHT, Clerk,	Headquarters.

ASSISTANTS FOR PORTION OF 1885.

BARD WELLS, Ass't Geologist in the Anthracite-Region, resigned June, 1885.

J. C. BRANNER, Assistant in the Anthracite-Region, resigned June, 1885.

H. N. SIMS, Assistant in the Anthracite-Region, resigned June, 1885.

CHARLES B. SCOTT, assistant at Headquarters, resigned July, 1885.

MICHAEL CARRAHER, messenger at Headquarters, resigned November, 1885.

SURVEY HEADQUARTERS, 907 Walnut St, Philadelphia.

A list of the publications of the Survey is appended to this report.

TABLE OF CONTENTS.

	Page.
Members Board of Commissioners, ...	iii
Survey Assistants, 1885, ...	iv
List of illustrations, Annual Report, 1885, ...	xiii

Report of the State Geologist for 1885.

By J. P. Lesley.

History of the Survey, 1874 to 1886, ...	xvii
Appropriations made for the Survey, ...	xxi
Persons engaged on the Survey since 1874, . .	xxii
Publications of the Survey, ...	xxiii
Progress of the Survey during 1885, ...	xxvii
Topographical Surveys, ...	xxxiii

Preliminary Report on Oil and Gas.

By John F. Carll.

Chapter I—On the oil horizons established by old and new borings, ...	1
Chapter II—On the question of the probable increase, stability, or decline of the oil production in the different districts, ...	12
Chapter III—On the relations of gas to oil, ...	30
Chapter IV—Theories of oil and gas, ...	42
Chapter V—What remains unchanged in our past knowledge of the Geology of Petroleum, . . .	54
Introduction, ...	54
General propositions, ...	61

Page.

The group of oil sands, ... 64
Confused nomenclature, ... 64
The sandy epoch, ... 69
Variable deposits—belt-lines and surface indications, ... 70
Anticlinals, ... 73
Theories for locating oil wells, ... 74
Recapitulation, ... 75
Practical deductions, ... 76
Necessity of preserving well records, ... 77
McKean and Warren, ... 78
Comparison of oil sands. 79
New fields opened, ... 79
Note and pursue the geological facts, ... 81

CHAPTER VI—Borings for oil in Jackson and Abbot townships, Potter county. Notes by Charles A. Ashburner, ... 82
Ohlen well, No. 1, ... 85
" " No. 2, ... 86
" " No. 3, ... 88
" " No. 4, ... 91

Vegetable Origin of Coal.

By Leo Lesquereux.

Proofs of the vegetable origin, ... 95
Objections to same, ... 97
Bischof hypothesis, ... 102
Grand'Eury, " 102
Vail, " 103
Kuntze " 104
Peat-bog theory, ... 105
Notes by J. P. Lesley, ... 120

Preliminary Report of work done in 1885, on the re-survey of the Pittsburgh Coal-Region.

By E. V. d'Invilliers.

CHAPTER I—Introduction, ... 125
Railroad and Miscellaneous Levels, ... 128

Page.

CHAPTER II—Structure, ... 159
1. Washington or Brady's Bend anticlinal, . . . 162
2. Pin-Hook anticlinal, ... 164
3. Roaring Run- (Peters' Creek) Murraysville anticlinal, ... 165
4. Waynesburg anticlinal, ... 165
5. Fayette anticlinal, ... 166

CHAPTER III—General Geology; Upper Productive and Barren Coal Measure Series; features of the Pittsburgh coal-bed, ... 171
Section of Upper Productive Coal Measures, . . . 172
The Pittsburgh coal-bed, ... 173
The Barren Measures, ... 177
Geology and Coal Developments of Lincoln township, Allegheny county, ... 181
Elizabeth township, ... 187
Forward township, ... 204
The Pittsburgh coal-bed, ... 206

CHAPTER IV—Notes on the Mountain Limestone (at the base of No. XI) in the Washington County Gas Wells, by Professors Alonzo Linn and Edward Linton, ... 222

The Coal-beds and Fire-clays of the Wellersburg Basin, in Somerset County.

By J. P. LESLEY.

General report, by J. P. Lesley, ... 227
Special report on fire-clay, by E. B. Harden, ... 329

Report on the Tipton Run Coal Openings, Blair County, (Coal-beds in the Pocono Formation, No. X.)

By CHARLES A. ASHBURNER.

General consideration of Pocono coals, ... 251
Pocono or No. X coals in Siding Hill tunnel, ... 252

Page.
Pocono or No. X coals elsewhere in Penna., ... 254
Tipton Run coals in No. X, ... 255
Allegheny Mountain section, ... 256
Sections of Loop Run coal-beds, ... 259
Analyses of Loop Run coal, ... 264
Fuel value of Loop Run coal, ... 265

Second Report of Progress in the Anthracite Coal-Regions—Part II.

By CHARLES A. ASHBURNER.

CHAPTER I—General description of the Anthracite Coal Fields.
1. Introduction, ... 269
2. Geography, ... 275
3. History, ... 277
4. Topography, ... 280
5. Structural Geology, ... 281
6. Stratigraphical Geology, ... 286
7. Mining, ... 296

CHAPTER II—The Classification and Composition of Pennsylvania Anthracites.
1. Classification, ... 300
2. Composition, ... 307

CHAPTER III—Survey of the Southern Coal-field, . . 325

CHAPTER IV—Survey of the W. Middle Coal-field, . . 333

CHAPTER V—Survey of the Eastern Middle Coal-field, 347

CHAPTER VI—Survey of the Northern Coal-field, . . 353

CHAPTER VII—Description of the Geological and Mine, and the Columnar Section Sheets, in the Northern Coal-field, ... 366
Nanticoke Mine and Geological Sheet, No. III, . . 372
Warrior Run " " " No. IV, . . 375
Plymouth " " " No. V, . . 376

Page.
Ashley Mine and Geological Sheet, No. VI, . . 381
Kingston " " " No. VII, . 384
Wilkes Barre " " " No. VIII, . 390

CHAPTER VIII—Basins and Anticlinals in the North-Coal-field.
Introduction, ... 398
Undulations of the Wyoming-Lackawanna Basin, 398
Descriptions of the Basins and Anticlinals of the Wyoming Valley, ... 404
Maltby Anticlinal, ... 406
Plains-Yatesville Anticlinal, ... 406
Henry Anticlinal, ... 407
Henry Basin, ... 407
Henry-Wyoming Fault, ... 408
Wyoming Shaft Anticlinal, ... 408
Mill Creek Slope Basin, ... 409
Mill Creek Slope Anticlinal, ... 409
Prospect Shaft Basin, ... 409
Prospect Shaft Anticlinal, ... 410
Cemetery Basin, ... 410
Cemetery Anticlinal, ... 411
Gas Works Basin, ... 411
Conyngham Anticlinal, ... 411
Conyngham Shaft Basin, ... 412
Hollenback Air-Shaft Anticlinal, ... 412
Baltimore Shaft Basin, ... 412
Baltimore-Stanton Anticlinal, ... 413
Empire Basin, ... 413
Stanton Anticlinal, ... 413
Stanton Basin, ... 414
Franklin Slope Anticlinal, ... 414
Newtown Basin, ... 414
Ashley Shops Anticlinal, ... 415
Petty's Pond Basin, ... 415
Stanton Bore-hole Anticlinal, ... 415
Ashley Cemetery Anticlinal, ... 415
Hanover Green Anticlinals, ... 415
Butzbachs-Buttonwood Anticlinal, ... 416

Page.
Behee's Pond Anticlinal, ... 416
Hanover Hogback, ... 416
Sugar Notch, No. 10 Breaker, Anticlinal, ... 417
Sugar Notch Tunnel Anticlinal, ... 417
Bennett's Creek Anticlinal, ... 417
Mocanaqua-Warrior Run Anticlinal, ... 417
Wanamie Slope No. 18, Anticlinal and Basins, . . 418
Newport Centre Anticlinals, ... 418
Newport Creek Anticlinals, Nos. 1, 2, and 3, . . 419
Honey Pot Tunnel Anticlinal, ... 419
Espy Run Anticlinals, ... 419
Reynolds Fault Anticlinal, ... 420

CHAPTER IX—Description of the Columnar Structure of the Coal Measures and Coal-beds contained in that portion of the Northern Coal-field covered by Geological and Mine Sheets, Nos. III to VIII, inclusive, ... 421

CHAPTER X—Report on the Wyoming Valley Limestone Beds, by Charles A. Ashburner, accompanied by a description of the Fossils contained in the same, by Professor Angelo Heilprin, . . 437

CHAPTER XI—Report on the Bernice Coal Basin, in the Loyalsock and Mehoopany Coal-fields, in Sullivan county, by Charles A. Ashburner.
General description, ... 460
Elevations, ... 464
Bernice Mines, ... 465
Description of Coal-bed A, ... 466
Description of Coal-bed B, ... 471
Composition, ... 476
Notes on the Mehoopany Coal-field, by Frank A. Hill, ... 486

Report on the Cornwall Ore Mines, Lebanon County.
By J. P. LESLEY and E. V. D'INVILLIERS. 491

Cornwall Trap Rock, ... 497

Page.
The Cornwall Ore Mass, ... 504
The Thickness of the Ore Mass, ... 505
The Ore Mass in Big Hill, ... 508
The Ore Mass in Middle Hill, ... 509
Copper in Middle Hill, ... 512
Grassy Hill, ... 512
Stratification of the Ore Mass, ... 513
The Interstratified Limestone Beds, ... 517
Mesozoic Formation at Cornwall, ... 525
Internal Constitution of the Ore, ... 530
The Chemical Constitution of the Ore, ... 531
Minerals found at the Cornwall mines, ... 546
Copper in the Cornwall ore, ... 548
The mining of Cornwall ore, ... 549

Some General Considerations Respecting the Origin and Distribution of the Delaware and Chester Kaolin Deposits.

By J. P. Lesley.

Strike of the strata in the kaolin district, ... 571
Erosion of the Palæozoic strata in Pennsylvania, . . 575
Limestone an agent in the kaolinization of feldspar rocks? 577
Demoralization of rocks, ... 578
Depth of the kaolin beds, ... 582
Chemical constitution of the kaolins, ... 585

Report on the Brandywine Summit Kaolin Bed, Delaware County.

By Charles A. Ashburner.

Location of Brandywine Summit kaolins, ... 593
Explorations on Griffen and Johns farms, ... 594
Decomposition of feldspar into kaolin, ... 598
Section on Johns farm, ... 600
Amount of kaolin on Griffen and Johns farms, . . . 604
Clay mining, ... 606
Preparation of clay for market, ... 611

Notes on the Quaternary Geology of the Wyoming-Lackawanna Valley in Luzerne and Lackawanna Counties.

Page.

I. Description of the Archbald Pot-Holes; also of the Buried Valley of Newport Creek, near Nanticoke, with special reference to the "Nanticoke Mine Disaster," of December, 1885, by Charles A. Ashburner, 615

II. Description of the Buried Wyoming Valley between Pittston and Kingston, by Frank A. Hill, . . 637

III. Description of a new substance resembling Dopplerite from a Post Glacial Peat Bog at Scranton, by Professor Henry Carvill Lewis, ... 647

Some General Considerations of the Pressure, Quantity, Composition, and Fuel-Value of Rock-Gas, or the Natural-Gas of the Oil Regions of Pennsylvania.

By J. P. Lesley.

1. Rock-gas pressure, ... 657
2. Rock-gas quantity, ... 666
3. Rock-gas composition, ... 671
4. Rock-gas fuel-value, ... 672

Report of the Progress of the Geodetic Triangulation of Pennsylvania.

By Mansfield Merriman.

1. The Nature of a Geodetic Triangulation, ... 681
2. The Methods of Geodetic Triangulation, ... 686
3. Progress of the Triangulation in Pennsylvania, . . 693
4. Geographical Positions and Results, ... 698

LIST OF ILLUSTRATIONS ANNUAL REPORT, 1885.

Plates Folded in Report.

Page.

General sections showing the relative positions of the petroleum and natural gas-sands, folded opposite page 4

Map of lands of the Summit Coal Company, folded opposite page 250

Map showing progress of survey of anthracite coal-fields, folded opposite page 272

Skeleton map of the Wyoming Valley, showing position of Mine Sheets I to VIII, inclusive, folded opposite page 354

Topographical map showing position of the Brandywine Summit kaolin-bed in Birmingham township, Delaware county, folded opposite page 594

Page Plates.

Skeleton geological map of Pennsylvania, opposite page i

General map of the anthracite coal-fields of Pennsylvania and adjoining counties, opposite page 269

Conventional characters adopted for the columnar section sheets of the Geological Survey, opposite page 295

Photographic plate of a model of Cornwall iron ore mines, (looking north,) opposite page 491

Photographic plate of a model of Cornwall iron ore mines, (looking south,) opposite page 495

Photographic plate, showing trap on the south side of the Cornwall Big Hill, opposite page 501

Photographic plate, showing prongs of trap on the Cornwall Middle Hill, opposite page 505

Page.

Photographic plate, upper ore stopes in the Cornwall Middle Hill, opposite page 509
Photographic plate, stratification of the Cornwall ore mass in the north wall of the deep ore cut Middle Hill, opposite page 513
Photographic plate, Cornwall magnetic iron ore workings in Middle Hill, opposite page 515
Photographic plate, showing the internal constitution of a block of Cornwall iron ore of low grade, opposite page 531
Photographic plate, Archbald Pot-Hole, No. 1, at Eaton colliery, looking into hole from above, opposite page 615
Photographic plate, Archbald Pot-Hole, No. 1, at Eaton colliery, looking into the hole from below, opposite page 617

Page and Text Cuts.

Map of portions of West Branch and Abbot townships, Potter county, ... 84
Skeleton sections of the Germania Oil Company's test wells, ... 92
The internal vegetable structure of coal, as seen through the microscope, ... 122
Map showing anticlinals and synclinals, Pittsburgh-Monongahela district, ... 126
Fire-clay mines, Savage Fire Brick Company, ... 240
Sketches showing sections at North Savage Fire-clay mine, ... 242
Illustration showing relationship of coal-beds in Loop run and Tunnel openings, ... 260
Cross section of Palæozoic strata, Carbon county, Pa., 281
Cross section of the Panther Creek coal-basin, ... 283
Columnar section coal measures, Nesquehoning tunnel, 290
Figures of Wilkes Barre Carboniferous fossils, . . 440, 442, 444, 446, 452, 453, 454, 455, 456, 457, 458
Map of Loyalsock coal-basin, ... 460
Map of Cornwall iron ore mines, ... 492

Page.
Section across Big Hill, combined with section along Furnace creek, ... 498
Sketch sections of stopes in Middle Hill and prongs of trap, ... 502
Cross sections of the Cornwall mine, ... 506
Section through Cornwall Big and Middle ore hills, . 510
Sketch map of little railroad cut at east end of limestone ridge, south side of Middle Hill, ... 516
Sections of west end limestone ridge, ... 520
Section along Cornwall railroad, ... 526
Sketch showing crush fault at Cornwall station, . . . 542
Bell magnetic iron ore mine, Dillsburg, York county, 566
McCormick magnetic iron ore mine, Dillsburg, York county, ... 568
Map showing location Brandywine Summit kaolin pits, 592
Map of Pit No. 1 and exploring shaft and drift on the property of the Brandywine Summit Kaolin Works, 596
Plan of the National Kaolin works, ... 610
Plan of the Brandywine Summit Kaolin works, . . . 612
Map showing topography in the vicinity of Archbald pot-holes, Blakely township, Lackawanna county, . 618
Sections of the Archbald pot-hole, ... 620
Map of the "cave" in the Ross coal-bed workings, Susquehanna Coal Company's slope, No. 1, ... 626
Map of the Old Buried Valley, between Kingston and West Pittston, ... 638
Geodetic triangulation figures, ... 683,692,699
Geodetic triangulation from Bear's Head Station, . . 690
Horse-shoe triangulation in south-eastern Pennsylvania, 696

Maps and Sections in Atlas.

1. Map of the Oil and Gas Regions of Pennsylvania and South-western New York. Scale, 6 miles to 1 inch, $\frac{1}{380,160}$th nature. See page 12.

2. Map showing the position of the Pittsburgh Coal-bed in Lincoln, Elizabeth, and Forward townships, Allegheny county, with contiguous territory along the Monongahela and Youghiogheny rivers, between McKeesport,

Columbia, and Port Royal. Scale, 200 rods (3300 feet) to 1 inch, $\frac{1}{39,600}$th nature. See page 125.

3. Columnar Sections of the Anthracite Coal Measures, showing the relationship of the coal-beds in areas mapped by the Geological Survey prior to January, 1886. See page 292.

4. Topographical map of the Wyoming-Lackawanna Valley. Scale, 3200 feet to 1 inch, $\frac{1}{38,400}$th nature. See page 360.

5. Topographical map of the Loyalsock Coal Basin. Scale, 800 feet to 1 inch, $\frac{1}{9,600}$th nature. See page 462.

6. Geological Map of the Cornwall Iron Ore Mines. Scale, 400 feet to 1 inch, $\frac{1}{4,800}$th nature. See page 491.

7. Map of the Kaolin Region in parts of Chester and Delaware counties, Penna., and New Castle county, Delaware. Scale, 1 mile to 1 inch, $\frac{1}{63,360}$th nature. See page 594.

8. Map showing the Geodetic Triangulation and Reconnaissance in Penna., January, 1886. Scale, 15¾ miles to 1 inch, $\frac{1}{1,000,000}$th nature. See page 697.

REPORT OF THE STATE GEOLOGIST FOR 1885.

To His Excellency, ROBERT E. PATTISON, *ex-officio Chairman of the Board of Commissioners of the Geological Survey of Pennsylvania :*

SIR : I have the honor to submit to the Board the following report of the progress of the Survey in 1885, with sincere expressions of gratitude for the generous and efficient support which the Board has given me in the execution of my plans, and equally sincere thanks to each and all of the gentlemen of the corps for their zealous coöperation.

A short history of the work of the Survey since 1874 will be the most appropriate preface to a statement of the work of the last year.

In 1874 the Survey was commenced in Venango and Butler, in Clearfield and Jefferson, in Mifflin and Huntingdon, in York and Adams, and in Lehigh county.

In 1875 it was continued in those counties, and was commenced in Greene, Washington, and Allegheny, in Cambria and Blair, and in Tioga and Bradford. A special survey of parts of Clinton was also made.

In 1876 the survey of the oil region was made to include parts of Warren and Crawford, Clarion and Armstrong. The rest of Allegheny was surveyed; half of Westmoreland and Fayette; all Beaver; half of Butler; all Somerset, Potter, and part of Snyder; and the survey of McKean

was commenced. The Lehigh work was extended into Northampton and Berks; the York and Adams work into Franklin and Cumberland.

In 1877 the survey of the oil region and that of McKean were continued; Westmoreland, Fayette, and Butler, were finished; Lawrence, Indiana, Lycoming, and Sullivan surveyed; the Blair county topographical survey extended; the South mountain topographical survey continued; the Northampton mountain and valley topographical survey extended into Berks; the survey of Juniata commenced; the topographical survey of the Seven mountains in Snyder commenced; the survey of Elk, Cameron, and Lancaster county commenced, and the outcrops of southern Bucks and Montgomery mapped and specimens collected.

In 1878 the survey of the oil region was continued; Mercer, Clarion, and Armstrong surveyed; McKean completed; Potter revised; Juniata revised and Perry surveyed; mapping in Blair finished; mapping of the Seven mountains continued; mapping of the South mountains continued; mapping of the Reading mountains continued; Lancaster completed; Southern Bucks and Montgomery mapped; and the museum arranged and catalogued.

In 1879 the survey of the oil regions was continued; Crawford, Erie, Jefferson, and Clinton were surveyed; the Elk and Cameron survey was extended into Forest, and the work in all three counties completed; the Franklin county valley was surveyed; the South mountain topography con tinued; the Reading mountain survey extended westward; the survey of the Philadelphia belt extended into Delaware county; and Chester county surveyed.

In 1880 the survey of the oil region was continued; the Coal Flora (collected, studied, described, and figured by Mr. Lesquereux since 1874) was published; the descriptions of the coal plants of Greene county were published; the subject of Waste in Anthracite Coal was studied; Susque-

hanna and Wayne county were surveyed; the South mountain topography was continued; the Cumberland county valley was surveyed; and the study of anthracite geology and mining methods commenced.

In 1881 the survey of the oil region was continued; Warren was surveyed; Pike, and Monroe, and part of Carbon were surveyed; a special palæontological survey of Perry and Juniata was commenced; and a systematic mine and surface survey of all the anthracite coal-fields was organized.

In 1882 the Anthracite survey was carried forward; Centre, Dauphin, Lebanon, Luzerne, Lackawanna, Columbia, Montour, and Northumberland counties were surveyed; the Perry county palæontology continued; the third and last volume of the Coal Flora published; the Report on Methods of Coal Mining completed; and the first sheets of the Anthracite Survey published. A special survey along the Lehigh river was commenced.

In 1883 a special survey of the Monongahela river collieries was made; the Clearfield county coal-fields were re-surveyed; Huntingdon county was finished; the roofing-slate belt in Northampton, Lehigh, and Berks was surveyed; the glacial moraine was traced across the State; the survey of the Anthracite fields was continued, additional sheets published, and a special topographical survey of the Wyoming coal field commenced. The Hand Atlas of counties was prepared for publication.

In 1884 the Anthracite surveys were continued, and some unfinished work in other parts of the State undertaken.

In 1885 there remained still unaccomplished a necessary revision of parts of Forest, Tioga, Bradford, Union, and Snyder, and of the whole of Juniata; a survey of the Pine-grove-Orwigsburg valley; some special local surveys in Cumberland, Dauphin, Lebanon, and Bucks; a systematic

survey of the Mesozoic country in Berks, Montgomery, and Bucks, and some important local surveys in Chester and Delaware, before the final preparation of the remaining volumes of county reports could be published. If the regular annual appropriation for the Survey had been continued all this could have been accomplished prior to 1885 without interfering with the progress of the Anthracite surveys.

But the appropriation made in 1885 was reduced to one half, and a new survey of the oil, gas, and coal-fields of Western Pennsylvania ordered by the Legislature of 1885. A new disposition of the force of the Survey had to be made, the proposed local work in the different counties named above postponed, and operations in the Anthracite fields restricted within narrower limits.

It is impossible to carry on a great work usefully without sufficient money. Skilled experts must be properly paid. Necessary expenses must be met. The most conscientious economy has its limits fixed by the nature of the undertaking. Personal zeal and a self-sacrificing love for and pride in good work of a noble kind can be carried to a certain height, and no higher. The State can do its geology, like the rest of its doings, only on business principles. What costs little is never good for much, and the utility of a geological survey to the Commonwealth will be exactly measured by the amount of time and money spent upon it. Fifty thousand dollars is not a large sum for a great State to spend annually in exploring its mineral resources, in making them generally known, and in obtaining or endeavoring to obtain explanations of natural facts which puzzle the best intellects. But the appropriation of 1885 only permitted an annual expenditure of twenty-five thousand dollars a year. Continual investigation is part of the price of human progress and national prosperity. The Geological Survey is only one kind of investigation among many others carried on by the people of Pennsylvania; but it is as necessary and as important as any other kind; and, being systematic, and based upon a store of real

knowledge, is one of the surest and one of the cheapest kinds.

The cost of the Survey was limited by the following appropriations:

Act of May 14, 1874, ...	$105,000
Act of May 13, 1876, ...	65,000
Act of April 18, 1877, ...	100,000
Act of June 11, 1879, ...	50,000
Act of May 26, 1881, ...	125,000
Act of June 28, 1883, ...	50,000
Act of July 3, 1885, ...	50,000
Total appropriation for 13 years, . .	$545,000

From May, 1874, to July, 1885, there was appropriated for the work of the Survey, $495,000, permitting an average yearly expenditure, for 11 years, of $45,000.

The expenses for the first six months of 1885, ($10,-194 45,) were met by the appropriation of June 28, 1883; and for the second six months ($14,489 30) by the appropriation of July 3, 1885.

Ttotal expenditure for 1885, $24,683 75.

Balance in hand January 1, 1886, to meet the expenses of 1886, and the first part of 1887, $35,510 70.

The amounts disbursed by the State Geologist, under the direction of the Board of Commissioners, have been accounted for by monthly detail vouchers, audited and approved by the Board, and deposited with the Auditor General of the State.

Persons engaged in the Survey and the length of time of their active connection with it previous to January 1, 1886.

	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.
Adachi, Jinzoo,	..	..	..	..	..	..	..	..	..	..	×	×
Aquirré, A. A., (1)	..	..	×	×	..	..	..	..	..	..	..	..
Albright, C. E.,	..	..	..	..	..	..	..	×	..	..	..	..
Albright, H. F.,	..	..	..	..	..	..	..	..	..	..	..	×
* Allen, Charles,	×	×	×	×	×	×	×	..	..	..	..	..
Ames, C. W.,	..	..	..	×	×	×	..	..	..	..	..	..
* Ashburner, Charles A.,	×	×	×	×	×	×	×	×	×	×	×	×
Beecher, C. E., (2)	..	..	..	..	..	..	..	..	×	..	..	..
Berlin, A. P.,	..	..	×	×	×	×	..	×	×	×	..	..
Billin, C. E.,	×	×	×	×	×	×	..	..	..	..	..	..
Branner, J. C.,	..	..	..	..	..	..	..	..	..	×	×	×
* Carll, J. F.,	×	×	×	×	×	×	×	×	×	×	..	×
* Chance, H. M.,	×	×	×	×	×	×	×	×	×	×	×	..
Clark, Ellis, Jr.,	×	×	×	..	..	..	..	..	..	..	..	..
Claghorn, R. C.,	..	..	..	..	..	..	..	..	..	..	×	×
* Claypole, E. W.,	..	..	..	..	..	..	..	×	×	×	..	..
Carraher, M.,	..	..	..	..	×	×	×	×	×	×	×	×
Chapman, M.,	..	..	..	..	..	..	×	×	..	..	..	..
Christian, G. H.,	×	×	..	..	..	..	..	..	..	..	..	..
Dager, J. H.,	..	..	×	..	..	..	..	..	..	..	..	..
* Dewees, J. H.,	×	×	×	×	×	×	..	..	..	..	..	..
* d'Invilliers, E. V.,	..	..	..	..	..	×	×	×	×	×	×	×
Eakins, L. G.,	..	..	..	..	..	..	..	×	..	..	..	..
Edwards, J. W.,	×	×	×	..	..	..	..	..	..	..	..	..
* Ewing, A. L., (3)	..	..	..	..	..	..	..	..	..	×	..	..
Fagen, H. J.,	×	×	..	..	..	..	..	..	..	..	..	..
Fellows, W. A.,	..	..	..	..	×	×	..	..	..	..	..	..
Flick, W. J.,	..	..	..	..	..	..	..	×	..	..	..	..
Ford, S. A.,	..	×	..	..	..	..	..	..	..	..	..	..
Forman, F. W.,	×	×	×	×	×	×	×	×	×	×	..	..
* Frazer, Persifor,	×	×	×	×	×	×	×	..	..	..	..	..
Fuller, J. T.,	..	..	..	..	..	×	..	..	..	..	..	..
* Genth, F. A.,	×	×	×	×	×	×	×	×	×	..	..	..
Griffith, William,	..	..	..	..	..	..	..	..	..	×	..	..
Halberstadt, B.,	..	..	..	..	..	..	..	×	×	×	×	×
Haldeman, B. F.,	..	..	..	..	..	..	..	..	×	..	..	..
Hale, A.,	×	×	×	×	×	..	..	..	..	..	..	..
* Hall, C. E.,	..	×	×	×	×	×	×	×	×	..	..	..
* Harden, E. B.,	×	×	×	×	×	×	×	×	×	×	×	×
Harden, O. B.,	..	×	×	×	×	×	×	×	×	×	×	×
Hartranft, S. S.,	..	..	..	..	×	×	..	..	..	..	..	..
Hartshorne, J.,	..	..	×	×	×	..	..	..	..	..	..	..
Hatch, F. A.,	×	×	..	..	..	..	..	..	..	..	..	..
* Hill, F. A.,	..	..	..	..	..	..	..	×	×	×	×	×
* Hunt, T. S., (4)	..	×	..	..	..	..	..	..	..	..	..	..
Kada, Teichii,	..	..	..	..	..	..	..	..	×	×	..	..
Lehman, A. E.,	×	×	×	×	×	×	×	×	×	×	×	..
Lehman, G. M.,	..	..	..	..	..	..	..	..	..	..	×	×
Lesley, Joseph, (5)	..	..	..	..	..	..	×	..	..	..	..	..
* Lesley, J. P.,	×	×	×	×	×	×	×	×	×	×	×	×
* Lesquereux, L.,	..	×	×	×	×	×	×	×	×	×	..	×
* Lewis, H. C.,	..	..	..	..	..	..	×	×	..	..	..	..
Lyman, B. S., (6)	..	..	..	..	..	..	..	..	..	..	×	..
Mansfield, I. F., (7)	..	..	..	×	..	..	..	..	..	..	..	..
* McCreath, A. S.,	×	×	×	×	×	×	×	×	×	×	..	..

	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.
McCreath, D.,	..	..	×	×	..	..	..	..	..	..	..	..
Merkle, J. F.,	..	..	..	..	..	..	..	..	..	..	..	×
Miner, Charles,	..	..	..	..	..	..	..	..	..	..	×	..
Morris, G.,	..	..	..	..	..	..	×	×	..	..	..	..
Moyer, H. I.,	..	..	..	..	..	..	×	×	×	×	..	..
Neitleton, E. S., (8)	..	..	..	×	..	..	..	..	..	..	..	..
Parrish, H. E.,	..	..	..	..	..	..	..	×	×	×	..	..
* Platt, Franklin,	×	×	×	×	×	×	×	×	..	..	..	..
* Platt, W. G.,	..	×	×	×	×	×	×	×	..	..	..	..
* Prime, F., Jr.,	×	×	×	×	×	×	×	..	..	..	..	..
Randall, F. A., (9)	..	..	..	..	..	×	..	..	..	..	..	..
* Sadtler, S. P.,	..	×	×	..	×	..	..	..	..	..	..	..
* Sanders, R. H.,	×	×	×	×	×	×	×	×	×	..	..	..
Scott, C. B.,	..	..	..	..	..	..	..	×	×	×	×	..
* Sheafer, A. W.,	..	..	..	..	..	×	×	×	×	..	..	..
* Sherwood, A.,	..	×	×	×	×	..	..	..	..	..	..	..
Simpson, G. B., (10)	..	..	..	..	..	..	..	..	..	..	×	..
Sims, H. N.,	..	..	..	..	..	..	..	..	×	×	×	×
Smedley, J. H., (11)	..	..	..	..	..	..	..	×	..	..	..	..
Smith, A. D. W.,	..	..	..	..	..	..	..	..	..	×	×	×
Somerville, B.,	..	..	..	..	..	..	..	..	..	..	..	×
Stinson, J. M.,	×	×	×	×	×	×	×	×	×	×	..	..
* Stevenson, J. J.,	..	×	×	×	×	..	..	×	×	..	..	..
Stockton, N. A.,	..	..	..	..	..	×	..	..	..	..	..	..
* Wall, J. S.,	..	..	..	..	..	..	..	..	..	..	×	..
Wells, Bard,	..	..	..	..	..	..	..	×	×	×	×	×
* White, I. C.,	..	×	×	×	×	×	×	×	×	×	×	..
Williams, T. J.,	..	..	..	..	..	..	..	..	..	×	×	..
Winslow, A.,	..	..	..	..	..	..	..	..	×	×	×	..
* Wright, G. F., (12)	..	..	..	..	..	..	..	..	×	..	..	..
* Wrigley, H. E., (13)	×	×	..	..	..	..	..	..	..	..	..	..
Young, C. A.,	×	×	×	..	..	..	..	..	..	..	..	..

(1) Special draughtsman for parts of two years.
(2) Special draughtsman for part of a year, (Fossils.)
(3) Special report on fossils of Centre county.
(4) Special report E.
(5) Special assistance in indexing.
(6) Special survey along the Connodogwinit creek.
(7) Special collection of coal-plants.
(8) Special oil-well records.
(9) Special report on Warren section and fossils.
(10) Special draughtsman, (Fossils.)
(11) Special notes on Serpentine localities.
(12) Special survey of parts of the Glacial Moraine.
(13) Special report J.
* Authors parts of reports.

The publications of the Survey have been—
1875, six volumes, B, D, H, I, J, M.
1876, four volumes, A, C, K, L, and a pamphlet B^2.
1877, five volumes, C^2, H^2, H^3, I^2, K^2.

1878, nine volumes, D^2, E, F, G, H^4, K^2, N, O, Q.

1879, three volumes, M^2, Q^2, V.

1880, twelve volumes, C^3, G^2, G^3, G^4, H^5, I^2, O^2, Pi, ii, P^2, Q^3, R, V^2.

1881, six volumes, A^2, G^5, H^6, M^3, Q^4, T.

1882, three volumes, C^6, G^6, T^2, and atlas (AA)1.

1883, seven volumes, AA, AC, C^4, D^3 (1), D^3 (2i), G^7, I^4, and atlas D^5.

1884, six volumes, H^7, K^4, Piii, P^3, T^4, Z, and atlas (AA)2.

1885, six volumes, AA^2i, C^5, F^2, R^2, T^3, X, and atlases (AA)3 (AA)4.

In eleven years the Survey has published 67 volumes 8° and one pamphlet, 4 anthracite atlases, and 9 other atlases to volumes AC, C^3, D^3, D^5, I^3, P, R, R^2, and T.

It has published *colored geological maps* of 57 out of the 67 counties. Colored maps of Cambria, Somerset, Juniata, Mifflin, Snyder, Union, Schuylkill, Berks, Montgomery, and Bucks being still unpublished; but *uncolored* geological maps of Cambria and Somerset are included in their volumes; and *colored* maps of the eastern half of Berks and of the southern parts of Montgomery and Bucks have been published in advance. All the county maps are on the scale of 2 miles to the inch, except McKean county and Philadelphia, which are on a scale of 1½ miles to the inch. Colored geological maps of all the counties, on a scale of 6 miles to the inch, prepared by the State Geologist at various stages of the Survey, will be found in the Hand Atlas (X) published in 1885.

All the volumes of reports, with three or four exceptions, are illustrated with diagrams, sections (columnar and horizontal,) sketches made in the field, local maps, and photographic views of such important outcrops as could not otherwise be described with requisite accuracy, amounting in all to several thousand.

The distributions of the publications of the Survey, by the Board of Commissioners, was regulated for ten years—that is, from 1875 to 1885—by section 10 of the act of May 14, 1874, which ordered that copies should be donated to all public libraries, universities, and colleges in the State, and

should be furnished *at cost of publication* to other applicants; the money received therefor being covered back into the State Treasury.

It was supposed that, by this proviso of the act, every citizen of the State who really valued a report would be easily able to obtain a copy, while no copies would be wasted, as by a free distribution. But, in point of fact, there was little or no sale, because citizens of the State were accustomed to obtain from their Representatives and Senators, without cost, all other State documents.

Consequently, when, in 1875, Report B, on the Mineralogy of the State, and Report J, on Petroleum, appeared, and a popular demand for copies of them was made on the members of the Legislature, who could not furnish to their constituents what they had to purchase for themselves, an act was passed providing for *a special edition* of 5,000 copies of each one of these reports, for the use of the Senate and House of Representatives. Similar acts were subsequently passed by the Legislatures of 1877, 1878, and 1879, respecting all the reports.

Under these acts, 425,931 copies of Geological Reports were printed for members of the Legislature and distributed by them among their constituency.

In addition to this, and under the organic law of the Survey, the Board published 110,569 copies, part of which were distributed to public libraries, universities and colleges in the State, and the remainder held for sale at cost. But the sale of reports was almost wholly stopped by the free distribution of the special Legislative editions; so that in 1885 there still remained unsold 43,118 copies.

In view of this fact, an act was passed and approved by the Governor, July 3, 1885, the first section of which enacted:

"That the Board of Commissioners of the Geological Survey are hereby authorized and directed to distribute the remaining copies of said reports as follows: Fifty copies of each report to the State Librarian for distribution and exchange with other States and Territories, and of the balance an equal number of volumes to each member of the present Senate and House of Representatives, making the sets complete as far as practicable."

The Board, before acting under this law, submitted the

same to the Attorney General of the State, and in accordance with the interpretation of the act received from the Department, the stock of reports was distributed as follows:

Copies retained for distribution to public libraries, universities and colleges in the State, under the act of May 14, 1874,	6,132
Copies (50 sets) delivered to the State Librarian,	3,600
Copies delivered to the Senate Librarian for distribution to the Senate,	7,040
Copies delivered to the Resident Clerk of the House of Representatives, for distribution to the members of the House,	26,162
Copies mislaid and discovered after distribution had been made,	61
Copies damaged,	123
Total,	43,118

The handling, recording, and distributing of so large a stock of publications, in a satisfactory manner, entailed a serious amount of time, labor, and expense, but it was all accomplished by the first of December.

The Board of Commissioners have now no reports on sale, as formerly, nor any copies for free distribution. But to meet necessary demands, copies will be purchased as occasions offer, and will be sold to applicants at cost of publication.

The future publication of reports is regulated by section 2 of the act of July 3, 1885, which reads as follows:

"That of each report hereafter published, three thousand five hundred copies shall be printed, which shall be distributed by the Board of Commissioners as follows: Five hundred copies to the Senate, two thousand copies to the House of Representatives, one hundred and fifty copies to the State Geologist, out of which he shall donate copies to authors and to members of Survey corps as heretofore granted, six hundred copies to the Board of Commissioners for distribution to public libraries, universities, and colleges in the State, to parties rendering material assistance to the Survey and for exchange with foreign societies and geologists, and fifty copies thereof to the members of the Board, one hundred copies to the Secretary of Internal Affairs, for distribution by him, one hundred copies to the Governor for distribution by him, and fifty copies to the State Librarian, for distribution and exchange with other States and Territories."

In consequence of this enactment, citizens of the State must apply to their Representatives at Harrisburg for copies of this Annual Report of 1885, as well as for any

future publications of the Geological Survey which they may desire to own.

Progress in 1885.

From the first of January to July 3, when the act of Assembly was approved by the Governor, the work of the Survey was limited to office work on the maps and sections of the anthracite region, verifying, correcting, and supplementing the data on which they were based by the necessary amount of field work and underground examination.

As soon as the continuance of the survey was assured, arrangements were made for resuming work in western Pennsylvania. Mr. Carll and Mr. d'Invilliers were recommissioned and took the field: the former to report on the gas-wells especially; the latter to report on the coal-beds of the Pittsburgh district. Part of the season Mr. d'Invilliers was directed to make a special survey of the Cornwall mine in Lebanon county.

Mr. E. B. Harden made a special survey of the Mt. Savage fire-clay mines in Somerset county.

Mr. Ashburner found time, in addition to that required for the discharge of his special duties as Geologist in charge of the Anthracite Survey and of the executive work of the entire Survey, to make a special study of the Tipton coal-beds in Blair county, and another of the kaolin beds in Delaware county.

Mr. Hill, as assistant geologist, has assisted Mr. Ashburner in continuing and extending the Anthracite Survey aided by Messrs. O. B. Harden, George M. Lehman, and A. D. W. Smith. Mr. Hill has rendered other efficient help connected with the general work of the Survey.

During the field season Messrs. J. F. Merkle and Bond Somerville were employed as volunteer aids on the anthracite work.

Mr. Baird Halberstadt has been engaged on accounts and general office work at headquarters, Mr. Adachi on draughting work, and Mr. H. F. Albright on general clerical work.

The curtailment by the Legislature of the appropriation of $90,000 asked by the Board for 1885 and 1886 to $50,000,

made it necessary to reduce the size of the corps, and Messrs. Wells, Branner, Sims, and Scott resigned their positions to form more lucrative connections. All these gentlemen were experienced in their special work, and their loss to the Survey was great.

In the early part of the year I was wholly occupied with the publication of such volumes of reports as appeared in the course of the year; that on Huntingdon county especially consuming much time. From July onward I was engaged in preparing a summary of the Geology of Pennsylvania for popular use. The call for such a work has been general throughout the State. Until now I have been unable to prepare it, owing to incessant demands made upon my attention. To relieve me of these interruptions, the Board approved of my delegating the executive business of the Survey to Mr. Ashburner, who was placed in charge of correspondence, publications, and accounts, with a general oversight of all field and office work. I hope by this arrangement to accomplish the serious task of publishing, in a single volume, a description of the State.

The Survey of the Oil Regions, by Mr. John F. Carll, has a special reference to the recent application of rock-gas to the iron and glass industries of the Pittsburgh district, and to the lighting and heating of houses, factories, and streets. Mr. Carll's preliminary report on rock-oil and rock-gas is the first in this volume. He will continue his survey of the region, and present a full report in 1886.

A sixth chapter has been appended to Mr. Carll's report, consisting of *Notes on Recent Oil-borings in Potter County*, in which Mr. Ashburner shows by their records that No. 1 well, which is only 2029′ deep, actually goes 169′ deeper into the measures than well No. 3, which is 2750′ deep, and goes 294′ deeper into the measures than well No. 4, which is 2100′ deep. It is an excellent lesson in oil geology. It shows, also, how properly kept well records can be used for discovering the true dip at great depths (see page 94,) and it indicates the probability that the Bradford Oil-sands of McKean do not extend eastward through Potter county.

I have added, on pages 657 to 680, a short discussion of the possible *quantity, pressure, and fuel-value of the rock-gas.*

The Survey of the Pittsburgh Coal Region, by Mr. E. V. d'Invilliers, begun in 1885, will be continued through 1886. In this volume is published his preliminary report on the underground structure of the area included between the Youghiogheny and Allegheny rivers; with maps showing the basining of the Pittsburgh coal-bed, and the irregular shape of the anticlinals. It deserves the careful consideration of those who are seeking accurate information respecting the *anticlinal rolls* of western Pennsylvania, under the mistaken supposition that they can be laid down upon the State and county maps in straight lines, and be used for locating new gas wells. The fact however is, that they are only approximately straight; that they are oblong elevations, rising and falling, sometimes running into each other, sometimes lapping past each other; that they are really the irregular wrinkles which separate and enclose a great number of synclinal dimples, rather than troughs; and that there are no such things as *cross anticlinals*, any more than there are *cross billows* on the surface of the ocean during a storm, the whole system of billows being arranged in one direction in nearly parallel lines, but each billow being composed of a multitude of waves arranged along a line. All this was made clear during the surveys of western Pennsylvania from 1874 to 1880, and appears in the county reports. Mr. d'Invilliers' work in 1885 presents the truth under more favorable circumstances for its accurate demonstration, and in greater detail than heretofore. He extended his survey beyond the district described, and will continue it over the whole Pittsburgh district in 1886, and report upon it in full for the annual report of that year.

I have obtained from the venerable botanist of the Survey, Mr. Leo Lesquereux (whose active employment on the Survey terminated in 1883, when the services of the chemist at Harrisburg, and the mineralogist at Philadelphia were also suspended) a concise statement of the grounds upon

which geologists base the now universally accepted theory of the *vegetable origin of coal-beds;* preferring it to come from his pen rather than from my own, because it is to his researches in early life into the nature and growth of the peat-bogs of Neufchatel and other districts of Europe that we owe the complete demonstration of the theory, whereas the direct study of the coal-beds has furnished only circumstantial evidence of its truth. The essay will be found on pages 95 to 121 of this volume.*

An important paper on the *Limestone of the Washington County oil wells* will be found on pages 223–227. The horizon of the *mountain limestone*, or sand-lime formation at the base of No. XI, has been established by Professors Linn and Linton, by a study of recent gas-well drillings. This is an important confirmation of and addition to our knowledge of the formations underlying western Pennsylvania and Ohio.

An account of the *Wellersburg coal-basin* in the southeastern corner of Somerset county will be found on pages 227 to 239 of this volume. It is extracted from a manuscript business report communicated to the State Geologist for the use of the Survey, by the late lamented James Macfarlane, one of its Board of Commissioners.

Mr. E. B. Harden's report of his special survey of the *fire-clay mines* of the basin is appended on pages 239 to 249.

Mr. Ashburner's report on his special survey of the *Tipton Run coal-beds*, in Blair county, will be found on pages 250 to 267. It fully substantiates the position always assigned to these early coal measures by the State Geologist,

*It seems strange that at this late day such proofs of the vegetable origin of coal-beds should be called for; but, during the last twelve months, the crudest notions on the subject have been published by respectable newspapers in the State, sometimes as editorials, sometimes as correspondence. One writer begins a defense of his "chemical theory" with the words: "The *American Cyclopedia* admits that there is no generally accepted theory for the formation of mineral coal." Another, who is a local authority in one of our bituminous coal regions, referring to a writer in a Western journal, says: "The main points in his article, so far as they treat on the origin of coal, whether objectionable or not, are preferable to the old vegetable theory; anything is better than that."

hundreds of feet beneath the coal measures of Clearfield and Cambria counties.

Mr. Ashburner's report of the progress of the *Anthracite Survey* will be found on pages 269 to 436. This part of the general survey of the State has been carried on continuously, through 1885, but with a diminished number of assistants, on account of the restricted appropriation; its operations being confined to the Western-Middle and Northern fields. No work was done in the Pottsville, Mine Hill, and Hazleton basins. A large amount of field and office work was accomplished, and a great mass of new data obtained, the discussion and verification of which for publication in topographical sheets, mine sheets, columnar section sheets, and cross section sheets, will occupy the whole of 1886 and part of 1887.

It is greatly to be regretted that the estimates of the State Geologist in the report of the Board to the Legislature were not accepted as a practical basis for the appropriation. Had they been, the corps in the Anthracite region would have been kept up to its standard size, and the amount of work doubled. The Survey of the Eastern Middle field would have been finished, and that of the Southern field extended from Tamaqua to Pottsville. The topographical survey of the Lackawanna basin would have been finished, and that of the Pottsville basin well under way. As it is, neither of these important parts of the work can be undertaken until after the next session of the Legislature.

Mr. Ashburner's special report on the *fossiliferous limestones in the anthracite coal measures* of the Wyoming valley (on pages 437–478) includes Prof. Angelo Heilprin's figures and descriptions of the fossils. No attempt has been made to correlate these limestone beds in eastern Pennsylvania with those in the western counties, but I am convinced that they represent each other, at least in part. If the 300′ of XII and 300′ of Allegheny coal series (together) are equivalent to the 507′ of XII and the measures up to the Baltimore Mammoth bed (see page 450); if the Mammoth represent the Freeport Upper coal; if the over-

lying 116′ sandstone represent the Mahoning; then the *Hillman limestone* (370′+ above the Mammoth) will occupy nearly the horizon of the *Crinoidal limestone;* the limestone 160′ higher will not be far from the *Elk-run limestone* of Somerset county; the *Canal limestone*, 130′ higher (660′ above the Mammoth), will fall into range with the limestones above the Pittsburgh coal-bed; and the *Canal* and *Mill Creek limestones* taken together will fairly represent the dying away north-eastward of the *Great limestone* of the Monongahela coal series.

The remarkable *pot-holes* near Scranton, and the *concealed gravel pit* at Nanticoke which produced the lamentable mine disaster in December, are described by Mr. Ashburner on pages 615 to 636, with maps of the localities.

Mr. Hill's report on the side limits of the *old buried valley of the Susquehanna*, from Pittston to Wilkes Barre, is given on pages 637 to 647. Both these reports exemplify the value of numerous bore-holes in advance of colliery workings.

To the above reports is appended (page 647) a description, by Prof. H. C. Lewis, of a mineral (*dopplerite*) frequently found in the peat-swamps of the region, which has excited a certain amount of speculation, requiring answers from the geologists of the Survey.

Mr. Ashburner's report on the *Bernice coal-basin* in Sullivan county occupies pages 459 to 490. Mr. E. B. Harden's map of the basin will be found in the atlas to the volume.

The report on the *Cornwall ore mine* in Lebanon county (pages 491 to 570) was prepared by Mr. d'Invilliers and myself conjointly, on the basis of his own surveys, topographical and geological, and my subsequent observation of the mine. I have given my reasons for believing in the existence of a great downthrow fault, of which he was not satisfied in his own mind, and for which he did not wish to assume any responsibility. His map of the mine in its present form is substituted for the old form of the mine in the body of a map of the region made by Mr. W. F. Shunk of Harrisburg, and communicated by the company

for the use of the Survey. This map will be found in the atlas to the volume. The illustrations of the report include two photographic views of models, one of the mine alone made by Mr. Harden, the other of the mine and surrounding region made by Mr. A. E. Lehman. Since the printing of the report I have had rock slices of the ore and limestone made for microscopic study, the results of which will appear in the next annual report.

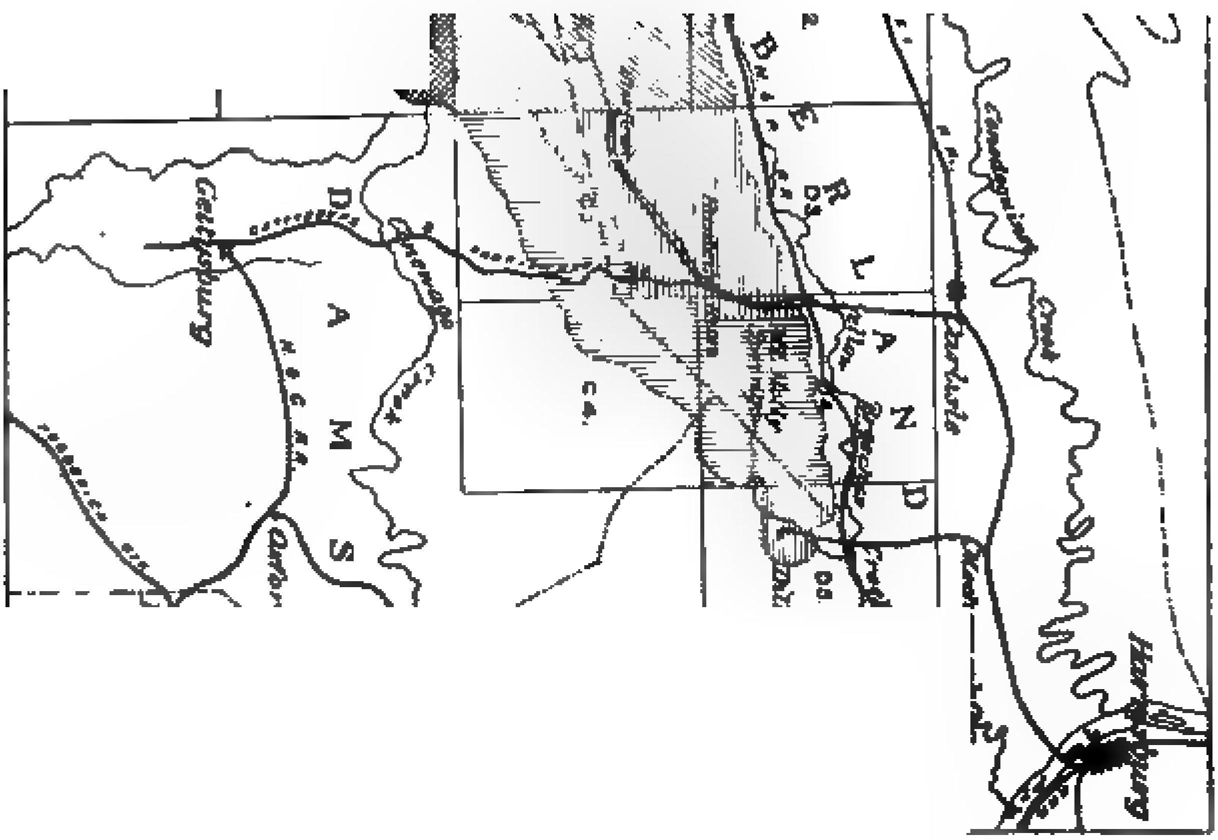
Mr. Ashburner's special report on the *kaolin deposits* of Delaware county occupies pages 593 to 614. A general map of the kaolin district, on both sides of the State line, will be found in the atlas to the volume.

I have ventured to prefix to that report (pages 571 to 592) a somewhat elaborate discussion of the probable origin of this remarkable and valuable mineral. I was influenced by the fact that there seems to prevail a complete ignorance of its circumstances. There is little or no popular elementary knowledge of the subject, and therefore a large amount of private observation is practically thrown away which, if communicated to geologists would throw needed light upon it. I have incidentally suggested, for the consideration of my fellow-workers in the science a possible explanation of the paradoxical Wealden clay formation. But there is another suggestion which might lead to better results, viz: The possibility that the Wealden clay-beds were originally deposits of nearly pure feldspar sand, and that they have been kaolinized in place under cover of the great porous calcareous Cretaceous and Tertiary formations.

A special report on the *progress of the triangulations of the U. S. Coast Survey in Pennsylvania* concludes this volume. The atlas map which accompanies that report shows that this important work, absolutely essential for the future preparation of a correct State map, has advanced so far as to cover one third of the State.

Topographical Survey.

The South Mountain topographical survey, by Mr. A. E. Lehman, was stopped for want of funds in 1883. But Mr. Lehman has since then done a great deal of voluntary


Gettysburg
Carlisle
Harrisburg

office-work, plotting survey lines, and drawing contour lines, to complete the unpublished sheets. He has even revised some of the old lines, and run such new ones in the field as he considered necessary for checking, tying, and rounding his work.

The accompanying page plate shows the condition of the work. (See page xxxiv.)

The plotting of sheets C 3, C 4, D 3, D 4, and D 5, was finished in the first quarter of 1885. The topography of D 3 was drawn in the summer; that of C 3 is in progress. The contouring of this sheet is done from the note-books of five field assistants engaged at various times and places since 1875. The same difficulties are encountered in finishing the other sheets, as Mr. Lehman works alone, without assistance. The larger portion of D 4, and all of C 4, have yet the topography to be placed upon them Sheet, D 5 has most of its topography finished.

What instrumental work was done in 1885, falls within the limits of C 3, special lines of survey being run in November, on account of recent important ore developments north of Hunter's run. The survey was extended over Piney mountain to locate limestone on the north slope, exposed in 1884. and furnishing dips which are of special importance, in view of a tradition that the limestone of the Mountain Creek valley appeared in the bed of the creek near Hunter's run. Much work was done at various times during the year meandering the creek for such an exposure unsuccessfully. A bore-hole drilled for water at the South Mountain Iron Company's mines, was expected to strike limestone, but it has gone down 400′ (that is, more than 200′ below the level of the creek-bed) without giving more than slight indications of limestone. Further up the valley however, in an ore bank on the Lehman tract, a decomposed limestone is sufficiently well defined.

Mr. Lehman made in the summer a reconnoissance of the mountain south-west of Boiling Springs, between the Petersburg road and Baltimore turnpike, for the purpose of finding traces of trap-rock, which would suffice to connect the Cumberland county trap-dyke at Boiling Springs

with the trap of York county; but the region is heavily wooded with much underbrush, and the ground covered with an accumulation of old leaves. The fragments of trap are very small, making the tracing of any trap-dyke difficult. As Prof. Claypole, in Perry county, could trace the trap-dykes across the valleys, but found their outcrops on the mountain slopes disappear before reaching the summits (see Report 2,) and concluded therefrom that the trap ascended only to certain heights, it is possible that the Boiling Spring dyke in its way under ground through the South mountains into York county may show itself only in the depressions of the surface and not show itself on the high grounds.

Mr. Lehman spent much time on sheets C 1 and D 2 in a fruitless endeavor to indicate on the blank part those sheets the geography of Cumberland and Franklin to the north of his proper field of work; that is, from the north foot of the South mountains, across the valley, to and beyond the Cumberland Valley railroad, as it seemed desirable to place on these sheets all the streams, roads, and villages in their general relation to the South mountain topography. But it was found impossible to make the two county maps agree; and when the railroad survey maps were used to interpret and adjust the disagreements, these were only increased thereby; nor will it be possible to present the geographical facts of the Cumberland valley with any correctness until a scientific topographical survey of it be made, based on triangulation; but for that work no money has been appropriated. These sheets are therefore left blank from the edge of Mr. Lehman's mountain topography northward. Had the blank space been filled with unreliable geography, the errors readily detected in it by citizens resident in the district would have justly cast suspicion of inaccuracy upon the mountain work, which has been done with such deliberation and exactness. These two sheets, C 1 and D 2, were put to press in December, 1885.

On the accompanying page plate the relation of the sheets of the whole South mountain survey to each other are exhibited.

During the progress of the Survey from 1874 to 1883, numerous special topographical surveys were made in sections of the State where such surveys were absolutely required in order to correctly explain the geological structure. In this way about 4,000 square miles of the State were mapped; but, on account of the restricted appropriations for the four succeeding years, the topographical work of the Survey has been restricted to portions of the anthracite region.

This has prevented the publication of a nearly completed topographical map of Southern Indiana and Northern Westmoreland counties, between Johnstown and Pittsburgh. The topographical map of the South mountain should be extended southward further into York county, nd north-westward so as to cover the limestone and iron ore belt of the Cumberland valley, as was done in Northampton, Lehigh, and Berks counties, and the two great maps should be connected by a belt of special surveys from Reading to Dillsburg, in York county. The limestone area west of Reading requires a great deal of special surveying.

The geology of Delaware and Chester counties will never be understood until every outcrop in the region is carefully located, the relief of the hills and valleys measured, and a detailed topographical map constructed.

Materials for a permanent geological map of the State have been collected during the course of the Survey, but we have no good topographical base for such a map.

The best map of the State which is now in existence is based upon a map made by authority of the Legislature, by an act approved the 19th day of March, 1816. This was known as Melish's State map, and it has furnished the frame-work of all subsequent maps of the State which have been constructed. Not a single county in the State is correctly mapped. In constructing a State map, these county maps might be combined, but, as they are all incorrect, they will not fit together.

Nothing but a topographical survey of the State, which will establish the true position of every point on its surface north and south, and east and west, from every other point,

and the elevation of every point on its surface above tide, will furnish its citizens with correct maps of their respective counties and townships, on which the county surveyors can then place the land lines, and geologists and mining engineers the mineral areas and outcrops. For a State so rich in minerals, this is a need of the first importance, and calls for it have been made from every quarter of the State.*

The topographical maps of special areas already completed by the Geological Survey for geological purposes make a large contribution of accurate maps toward a general topographical survey of the State, which would, in fact, be only a continuation of the work of the Geological Survey.

The United States Coast and Geodetic Survey, under authority of Congress, which permits them to assist State Surveys, is now making a triangulation survey of the State and obtaining the true longitude and latitude of prominent points in the State, so that this work will form a valuable and necessary basis for the topographical mapping which should now be undertaken by the Geological Survey. Some of the errors on the best State and county maps which are now in existence, which have been detected by the work of the United States Coast Survey, are very large.

To continue the topographical surveys already begun and to commence a topographical map of the State, which shall be published on a scale of one mile to one inch, an annual appropriation of at least $10,000 will be required.

The United States Surveys, acting under authority of Congress, in the latter part of 1884, made the following propositions to the Board of Commissioners, the acceptance of which by the Board depended upon the appropriation for the State Survey being secured.

(1.) The Director of the United States Geological Survey offered to coöperate with the State Survey in the topo-

*See proceedings of Convention of County Surveyors in Harrisburg, October, 1880, and the annual report of 1883 of Hon. J. Simpson Africa, Secretary of Internal Affairs.

graphical mapping, and to expend in the State $30,000 annually.

(2.) The Superintendent of the United States Coast and Geodetic Survey offered to coöperate with the State Survey, and expend in the State $5,000 annually, in order to push more vigorously the triangulation of the State, which must of necessity precede the topographical work.

The Board of Commissioners therefore recommended to the Legislature of 1885 that an appropriation of $10,000 a year for 2 years should be made. Had that appropriation been made, it would have effected an actual annual expenditure for this purpose of $45,000 by the three Surveys (State Geological Survey, $10,000; U. S. Geological Survey, $30,000; U. S. Coast and Geodetic Survey, $5,000) in extending the triangulation and the topographical mapping of the State, which has been slowly progressing for the past ten years; the triangulation work under the Coast Survey, and the topographical work under the State Survey. It is estimated that this mapping of the State will cost $500,000, which would require the State Survey, unaided, fifty years to complete, with an annual expenditure of $10,000. Such an independent Survey is now being made by the State of New York.

If the Pennsylvania Survey shall coöperate with the U. S. Surveys, the work can be completed in ten years, with an expenditure on the part of the State in that time of about $100,000.

The U. S. Surveys are now coöperating with the State Surveys of New Jersey and Massachusetts in constructing topographical maps of those States. In the case of these two States, however, the U. S. Geological Survey is not bearing as great a proportion of the expense of the work as was proposed for Pennsylvania.

Very respectfully,

J. P. LESLEY,
State Geologist.

PRELIMINARY REPORT

—ON—

OIL AND GAS.

BY JOHN F. CARLL.

CHAPTER I.

On the oil horizons established by old and new borings.

The appropriation, made by the Legislature of 1883 for the Geological Survey of Pennsylvania provided for continuing work in certain portions of the State not embracing the oil regions, consequently that branch of the survey had to be discontinued. After an interruption of over two years, the present investigations were authorized by Act of the last General Assembly, and work commenced on the 15th of July, 1885, with the requirement that a preliminary report of progress should be furnished for the annual report of 1885.

The years 1883-4-5 were crowded with occurrences of great import to the oil and gas-producing industries. The history of these years records the outlining and steady decadence of the great Bradford and Allegany oil fields; the renewal of extensive operations in the white sands of the Venango-Butler group; the rise and fall of Cooper, Henry's Mill, Balltown and Wardwell pools, in Warren and Forest counties; the rocket-like career of Thorn Creek, in Butler county; the opening of Kinzua, in Warren county; Red Valley, in Venango county; Cogley Run, in Clarion county; Washington, in Washington county, and several other pools and extensions in the old districts. It has also witnessed a most astonishing development of natural gas territory surrounding the city of Pittsburgh, and an unexampled diligence and perseverance of prospectors for oil and gas in every portion of the State

west of the mountains, and in the adjoining Commonwealths of Ohio and West Virginia.

In a field so broad geographically, and, in consequence of such wide-spread developments, presenting so many debatable subjects for geological investigation, a great deal of time is necessarily consumed in collecting the facts which affect so wide a scope of country, and so thick a vertical section of rocks, before the systematic study of the structure can be resumed, which was interrupted more than two years ago. This preliminary report, now called for, must be confined to a brief generalization and illustration of the most important recent revelations of the drill.

The defective manner in which ordinary well records are kept (being generally only memoranda of a few meager facts which the driller thinks it worth while to charge his memory with), and the difficulty of obtaining even these fragmentary data for publication, have been frequently referred to in former reports.* What has there been said may be reiterated with emphasis here, and with regret I am compelled to add that the disposition to secrete facts and to mystify everything connected with new developments, which manifested itself only in exceptional instances a few years ago, has now become one of the most pronounced characteristics of every shrewd prospector for oil or gas. Every new well is watched by a score of outsiders, eager to secure a hint or suggestion that may enable them to profit by the results of a venture in which they have not risked a dollar, and who will not hesitate to use any information obtained, even to the detriment and financial harm of the parties furnishing it. Therefore, it seems natural for it to have become an instinct of self-protection that every operator should carefully guard the secrets disclosed by his drill. Business prudence forbids any revelations that might furnish others a clew to work upon. Few extensive operators now attempt to disguise these facts, and they frankly tell me they will furnish no precise information, concerning their wells, except with the explicit understanding that the

---

*See Reports I, p. 42; I[3], Chapters XVIII and XIX; I[4], p. 382.

facts shall be used only for geological purposes, and the deductions published in a general way, without such details as might betray the exact source from which the information came. In justice, then, to those who have given their records without reserve, I have decided not to publish any detailed well records at present, but will retain them for a future report, when, no doubt, the restrictions will be removed from many of those which cannot be published now.

Although several new oil and gas pools have been opened in Pennsylvania since the oil region survey terminated, at the close of 1882, there is nothing to indicate, (as far as present information goes) that any *new productive horizons* have been discovered. This is rather remarkable when we consider the possibilities, and how persistently the drill has been at work in every part of the country—all along the right and left flanks of the oil belts extending from St. Joe in Butler county to Allegany county, New York—on the north-east and south-west ends of them—seeking for pools within their acknowledged limits—and delving deep below the rocks now producing, in quest of other oil sands; but, nevertheless, it appears to be true, as a review of the several oil districts in detail will show.

In the black sands of Bradford and Allegany nothing new has been found. Many wells in Bradford have been deepened to the so-called Bradford Fourth sand; but this rock is merely the lower member of the Bradford group of oil rocks, as the Butler Fourth-sand is the lower member of the Butler group. All the shows of oil or gas obtained by drilling below the Bradford-sand, in the southern part of McKean county and in Elk county, can be referred either to the Sartwell-Smethport sand or the gas-sand, found as early as 1882, in the Roy and Archer and several other wells in Elk county.

In the white sands of Warren and Forest counties, all the new production of either oil or gas comes from some one or other of the previously described horizons; no productive white sand beds have been found below the Cooper-Blue Jay-sand.

Deep drilling south-westerly from Forest county, extending through Pittsburgh and Washington county to the West Virginia line, has brought to light no productive rocks below the Venango-Butler group, except in one spot in Cranberry township, Venango county, where a large deposit of gas is found in an extension of one of the sands of the Warren group. Southwest of Cranberry, (so far as can be learned,) no favorable indications have been seen in any of the deep wells, after passing through the Venango-Butler group. It is evident that the gas wells surrounding Pittsburgh draw from the sands of this group and from sands *above* it, as do also the oil and gas wells of Allegheny, Beaver, and Washington counties.

There is no *new feature*, then, to be introduced in carrying forward a study of the oil and gas rocks. The developments of two years and ten months, during which time 7,200 oil wells and over 100 gas wells have been drilled, amply confirm the views of stratigraphical order advocated in former reports, and we now have the means of tracing the Venango-Butler group quite satisfactorily from Tidioute, in Warren county, to Washington, in Washington county, a distance in a direct line of about 115 miles. Of course, the group varies greatly in details of structure in different parts of this area, as has already been shown,* and as new developments prove; but wherever it is present, it can be easily recognized in every properly-kept well record.

Every division of the oil region has at least one well-defined, persistent stratum, upon or near the surface, which may serve as a guide or key in studying the geological structure below it. Such is the Olean-conglomerate all along its north-western and northern outcrop; the Subolean in the counties of Forest and Elk; the Ferriferous limestone in the Butler and Clarion fields; the Pittsburgh coal-bed and Crinoidal limestone in the vicinity of Pittsburgh. All these rocks are deeply buried in the south-western angle of the State, but their gradual rise north-

*Report I, pp. 23-32, and I^3, Chapters XIV and XIX, and Charts.

ıber of the
nglomerate No XII)

500

2100

Oil Sand

eastward brings them one after the other up to daylight. First, the Pittsburgh coal runs up into the hill-tops and disappears, only a few of the highest knobs north of Pittsburgh being high enough to hold it; then the Ferriferous limestone, in like manner, runs out before reaching the Allegheny river near Franklin; while the Olean-conglomerate reaches as far north as Meadville, in Crawford county, and trends off towards the north-east with an irregular outcrop to Olean Rock City, in Cattaraugus county, N. Y., just north of the Pennsylvania line, where its top has an altitude of 2,400 feet above ocean level. In Boyd Hill well, Pittsburgh, the probable representative of this rock is found 224 feet below ocean level, or 2,624 feet lower than at Olean Rock City. Hence (the distance between the points being about 131 miles), the south-westerly dip of the stratified rocks averages about 20 feet to the mile.

To show the positions of the several oil and gas-producing horizons relatively to these key-rocks, in localities where the latter are well defined, three vertical sections are appended. all drawn to a scale of 1 inch to 200 feet.

No. 1 shows the mean distances between the base of the Olean-conglomerate and the several oil and gas horizons noted, as indicated by records of wells drilled throughout the range of country to the north-west and north of the Ferriferous limestone outcrop, and where the Olean is plainly recognizable. The Sub-olean is placed in the section 50 feet below the Olean—the usual interval north-west of the Allegheny river. But, going south-easterly from Great Bend and Warren, this interval widens until it attains a thickness of 200 feet or more on the Clarion river. Hence, the Olean-conglomerate is not as desirable a base for comparison as the Sub-olean in Elk county and the south-eastern part of Forest; for the facts, as far as can be judged. indicate that the strata underlying this wedge-shaped interval between the ovoidal pebble (Olean) and flat pebble (Sub-olean) conglomerates, run more nearly parallel with the Sub-olean than the Olean. Quite possibly, then, as this section is keyed upon the Olean, some of the horizons which appear upon it 50 or 100 feet apart may fall into

one and the same plane when an allowance is made for thickening or thinning of the intervening rocks in proper directions. It should be understood that these sections have not been adjusted to show equivalence of strata; they simply give a general idea of the approximate relations of the several oil and gas horizons to certain well-known rocks upon or near the surface.

No. 2 has the Ferriferous limestone for its datum, and is applicable principally to the wells of Butler and Clarion counties. This, also, must not be taken as a scale of absolute distances; for, although the Ferriferous is one of the most reliable guides the driller has ever had to work from, the interval between it and the oil group varies considerably in different places, as mentioned in I^3, page 100.

No. 3, commencing with the Pittsburgh coal, and also carrying the Crinoidal and Ferriferous limestones, is intended more especially to represent the section in the immediate vicinity of Pittsburgh. Here the Ferriferous is very thin, and has been noticed only in three or four wells, where it was closely watched for at the proper spot. The horizons noted on this section will need considerable adjustment to bring them into their proper places. First, because the Lower Barren Measures beneath the Pittsburgh coal vary in thickness in different places, being about 600 feet thick in Allegheny county (Q, p. 24), 540 feet in Beaver county, and 425 feet in Greene county (K, p. 75). And, second, on account of a new element coming into the section —the Silicious limestone—first detected in Boyd Hill well in 1877, and since found in every well near Pittsburgh and Little Washington, where the sand-pumpings have been tested. It is mistaken for a fine white sand by well-borers; and, as it lies within the range of the mountain sands, they never take the trouble to preserve specimens of it. Hence, we have no means of determining at what point north of Pittsburgh it first appears, or how much it may affect the parallelism of the strata above and below it. It is evident, therefore, that any oil or gas-rock underlying the area covered by this section, may be found in one place at a certain

distance below the Pittsburgh coal, and in another place at a greater or less distance below it.

By placing these three sections side by side, with the top of the Venango-Butler group coinciding with a horizontal line, a very good general idea of the relative positions of the different oil and gas horizons may be obtained. They also show how far our deepest wells have been sunk below the productive sands.

It will be observed that Fagundus well, No. 37, Warren county, (I^4, p. 283,) is about as deep, geologically, at 2,700 feet, as the Buchannon well, in Washington county, (the deepest bore hole in Pennsylvania,) at 4,303 feet—provided all the formations pierced run through regularly; and that the Watson well, near Titusville, (I^3, p. 154—I^4, p. 284,) in drilling to a depth of 3,553 feet, passed through about 1,100 feet of still deeper and older rocks, which have never been reached by any other well on the Pennsylvania oil belt. Fagundus well, No. 37, although located but a few miles west of Warren and Forest developments, found scarcely a trace of any of the sands so prolific at Clarendon, Cherry Grove, Cooper, and Balltown, having drilled through nothing but homogenous masses of slates and shales after leaving the Venango oil group. Clapp well, No. 45, (I^4, p. 280,) drilled to within 150 feet of the same depth, gave a similar record. Some sands were reported in the Watson well. They may be there or they may not. The history of the well is so unreliable that it would not be wise to base any conclusions upon it. We only know, that after casing, it was a perfectly dry hole, giving no indications of either water, oil, or gas. The record of Buchannon well has not been published, but the version of it in my possession is so indefinite, I am forced to conclude there were no thick, massive, or well defined sandstones encountered below the sandy measures lying in the horizon of the Venango-Butler group.

In comparing sections of this kind, it will not be expected by any one acquainted with the variability of sedimentary deposits, that the vertical distance between any two well-known layers will be exactly the same in every place where

it is measured. If two rocks were deposited in absolutely parallel planes, with, say, 1,000 feet of sand and mud between them—in some places 800 feet of sand and 200 feet of mud, in others 800 feet of mud and 200 feet of sand—the original parallelism would be completely destroyed when the whole mass became indurated into sandstone, and slate, and shale, by reason of the unequal shrinkage of the compressible mud and almost non-compressible sand. But the materials were not deposited evenly, except over limited areas and in certain directions. An evident change in structure occurs in going transversely to the general lines of deposition, as has been shown in former reports.

The First oil-sand of the Venango group can be traced, without a possibility of mistake, from Oil creek, where it received its name, to Bullion, near the north line of Butler county. There the Ferriferous limestone comes into the hill-tops, and the interval between the two rocks is about 870 feet. All along the north-westerly edge of the Butler oil-field this interval remains remarkably constant, and the identification of the First-sand is further assured by the presence of the great red rock above it, which, in turn, is overlaid by the Pithole grit. At Petrolia the red rock has disappeared, and the Pithole grit, if present, is not in its normal position; for, in place of a central sandstone in the shales between mountain sands and oil group, two sandstones appear, one above, the other below the center. The lower one is the rock erroneously called by drillers "First sand." (See I^3, pp. 107–110.) The interval here between the Ferriferous limestone and *true* First-sand is about 920 feet.

In the Thorn Creek district, the so-called "Gas-Sand" lies about 770 feet, and the "Hundred-Foot Rock" 920 feet below the Ferriferous limestone, and the general features of structure, traced through wells from Petrolia to Thorn creek, force the conclusion that the Thorn Creek "Gas-Sand" is the equivalent of the "Petrolia First-Sand," and the "Hundred-Foot Rock" the true First-sand of the Butler oil group, which has gradually augmented in thickness in

going in a south-westerly direction. So far, then, the tracing of the Venango-Butler group can hardly be questioned.

Now, advancing to Pittsburgh, we find the great "Salt-water rock" 100 feet, more or less, in thickness, with its top about 800 feet below the Ferriferous limestone, and a representative of the Thorn Creek gas-rock from 70 to 80 feet above the salt-water sand. This structure is somewhat different from that shown in the Boyd Hill well, but it is amply confirmed by many wells since drilled near Pittsburgh, and between the city and Thorn creek. These facts seem to furnish a reasonable demonstration that the Pittsburgh Salt-water rock is the southern representative of the First-sand of the Venango-Butler oil group.

Several deep wells have been sunk in Pittsburgh and vicinity, and it is now known that other sands, with red rocks, similar in appearance and constitution to the Venango-Butler group as it appears along its south-eastern edge, (see I[3], Plate V), extend down about 500 feet from the top of the Salt-water sand, and then come the typical Chemung slates and shales, which have been pierced to a depth of about 950 feet, with scarcely a change worthy of note.

It may be noticed on Section No. 3, that all the oil and gas horizons of Westmoreland, Allegheny, Beaver and Washington counties come either in the range of the Venango-Butler group or some of the sands above it. When the proper adjustments are made for the varying thicknesses of intervening strata, some of the horizons noted will be found to belong to the Thorn Creek gas-rock, while the majority of them will fall into the Venango-Butler group. The data required to work out these adjustments satisfactorily have not yet been obtained. In fact, drillers do not keep their records in this portion of the well with sufficient accuracy for the purpose, even if there was no disposition to make matters as *cloudy* for others as possible. Large gas wells must stop drilling when heavy flows are struck, and, generally, they are only a few feet in the sand. Consequently, nothing can be learned of the strata below, and where the rocks are so variable, and gas is found at different horizons in them, a satisfactory comparison of one well

with another cannot be made unless the records have been kept in minute detail for two or three hundred feet above the gas-sand.

Over thirty-five wells have been drilled in the Murraysville district, and, as all of them are large producers, there has been no necessity for drilling through the sand. Hence, the sub-structure there is still unknown. The identity of the gas-sand with the upper member of the Venango-Butler group seems to be confirmed, however, by its position in relation to the Crinoidal limestone, Mahoning sandstone and Freeport coal. There is a sandstone about 80 feet above its top, which seems to correspond to the Thorn Creek gas-rock, and which here contains some salt-water.

One important fact appears to be pretty clearly established by the wells already drilled in Pittsburgh and vicinity. Wherever the sand has a thickness of from 80 to 110 feet, it is always a reservoir for salt or brackish water. For this purpose it is constitutionally adapted, being rather a coarse-grained, even-textured sand-bed throughout. It has the appearance of having been deposited as an extensive sand-bar at the mouth of some ancient stream, where the current, freighted with a large percentage of sand, met its first check and dropped its coarser materials. evenly-assorted and in large quantities. Around the edges of the central mass are a number of irregular thinner beds, which often contain coarser materials, and seldom have an individual thickness of over 20 feet. Some one or other of these layers appears to furnish the gas at Tarentum, Leechburg, Murraysville and Washington.

A rock so uniform in thickness and structure naturally affords a good medium for the circulation of fluids, and as it has a dip towards the south-west and south, quite sufficient to sensibly affect any possible underground drainage, it is not surprising that it is now full of water in the neighborhood of Pittsburgh. It appears to have been traced in maximum thickness from Butler to McKeesport, a distance of about 40 miles; and wherever drilled into along the trend of best development, presents very similar characteristics. An average dip of 20 feet to the mile (it prob-

ably exceeds 20 feet in this direction) would give the underground water-beds in the sandstone a fall of 800 feet in 40 miles—100 feet more fall than the waters of the Ohio river, have in traveling about 2,100 miles, from Pittsburgh to the Gulf of Mexico. The upper and lower oils in the Gordon well, at Washington, Washington county, come, if we judge correctly, the first from a sandstone lying at the top, the second from a sandstone lying in the central part of the Venango-Butler group as represented at Pittsburgh; and it is quite probable that other sands belonging to the bottom of the group will be found, before the homogeneous undershales are reached. But, as no wells have yet been drilled deeper in that locality, and the record of this well is not given with sufficient clearness and detail to justify basing conclusions upon it, we must await further developments by deep drilling between Little Washington and Pittsburgh, before the *exact* horizons in this new field can be definitely announced.

To the north and north-west of Washington, as far as Beaver Falls and Smith's Ferry, all the developments indicate that important changes occur in the stratigraphical order and character of the rocks below the Mountain sands. This is a part of the middle ground between the south-westerly dipping deposits of Pennsylvania and the south-easterly sloping rocks of Ohio; and it will be strange indeed if the whole country south of the Ohio river and west of the Monongahela, should not be found to be a region of considerable irregularity of structure, requiring a close and patient study of details and the drilling of many unsuccessful wells to unravel its intricacies.

CHAPTER II.

On the question of the probable increase, stabilty, or decline of the oil production in the different districts, as indicated by their more recent history.

The different petroleum districts are shown upon a map accompanying this report, prepared in 1884, and printed in January, 1885, for the service of the Oil Region. A part of the edition was reserved for publication with this report; and, upon the sheets thus reserved, all the oil-pools discovered since the map was drawn, and the gas-pools now so largely exploited, have been printed in separate tints. A new and more detailed map of the region will be prepared for the report of 1886.*

The Allegany District, (of New York.) although not directly within the province of the Pennsylvania Geological

*Before the survey of the Oil Regions was interrupted, I had contemplated the preparation of such a map of Western Pennsylvania and New York, with all the known oil areas located upon it in their true geographical relations; but, as a new draft needed to be constructed for the purpose, the exact location and outlining of the numerous pools, (some of them almost forgotten) required more time and assistance than I had at my disposal. In 1884, however, such a map was undertaken at the general office of the Survey in Philadelphia, on which I might locate the oil-pools; but, as my connection with the Survey had been suspended, my occupations permitted me neither to superintend personally the construction of the map, nor to give all the necessary attention required for the exact correction of the proof-sheets. In spite of these circumstances it is, without doubt, the most reliable sketch of the oil regions ever published, and, if the oil-pool areas be regarded as they are intended to be, simply as indications of the localities where oil has been found, and not as exhibiting the absolutely *exact* outlines of the areas of production, it will fulfill its purpose and be appreciated by those who have occasion to use it. No correction of the original map, printed in January, 1885, could be made; but only a second printing upon them of additional matter, as described in the text. These additions may be said to represent the results of two years' active work by the drill, say from November 1st, 1883, to November 1st, 1885; and the present chapter is a brief review of each district separately, as marked upon the map, considering what the developments indicate geologically in relation to further extensions of productive areas and the continuance of future supplies.

Survey, is intimately connected with the petroleum interests of our State—its wells being largely owned and managed by Pennsylvania men, and its geology a counterpart of our own—and naturally comes first under consideration in any discussion of the Pennsylvania oil fields.

Some enlargement of its territory (not shown on the map) has more recently been made, principally towards the north, between the main pool and Clarksville and Niles; but while the acreage has been thus considerably increased, the wells are small. The field has now been so thoroughly developed within its acknowledged boundaries and in all directions around its edges, without encouraging indications of new oil horizons or of important extensions of the old, that there is little prospect of maintaining, much less of increasing its present output.

This has been one of the most remarkable districts of the oil regions. Situated in an old settled country, with good highways, and fair railroad facilities, which were speedily increased by interlacing lines of narrow-gauge railroads, making every portion of it conveniently accessible; with shallow and exceptionally favorable drilling, where it was possible to drill two wells a month with one set of tools; with a sand like Bradford, brown, homogeneous, fairly uniform in thickness and always remuneratively productive within defined limits; and coming into notice as it did at a time when there was considerable well machinery not very profitably employed in the Bradford region, and a scarcity of attractive territory visible there—this Allegany district was developed with unexampled rapidity, as the following approximate statistics from the *Petroleum Age* show:

1881. Active developments commenced with the Richburg and McBride wells about May 1st.

1882. Maximum production reached in May.*

Daily average for the month, 22,438 barrels.

*Pipe line runs in May, 19,522 barrels; in July, 23,881.—From which it might be inferred that the maximum production was attained in July. But in May the lines were not able to run the oil as fast as produced, and it accumulated in tanks at the wells. In July, with increased facilities, they were drawing upon these accumulations.

Wells drilled, 1,757 ; of which 128 were dry.

1883. Average daily production in October, 13,089 barrels.

Wells drilled, 3,315 ; of which 216 were dry.

1885. Average daily production October, 6,747 barrels.

Wells drilled, 4,326 ; of which 294 were dry.

Some wells in the district have been, abandoned and the *Age* estimates that on November 1st, 1885, 3,980 were producing ; which gives a daily average of only $1\frac{7}{10}$ barrels to a well. At its maximum in 1882, the daily average per well was about 14 barrels.

It seems from these statements that during the last two years the daily production has fallen off 6,347 barrels, or about 48½ per cent, notwithstanding the completion of 1,011 new wells ; a fact which unmistakably foreshadows the fate of all oil and gas fields when rapidly and thoroughly perforated.

The Bradford District needs no material change of its outline on the map. Some very prolific reserve-tracts near its south-easterly border have been quietly depleted, and promising spurs along other parts of its edges prospected. Within its defined limits many new wells have been sunk, and hundreds of old ones deepened to the so-called Fourth-sand, and stimulated by the explosion of enormous charges of nitro glycerine ; but still the production wanes. It is apparent that this great district, which in ten years since 1875 has furnished about 120,000,000 barrels of oil, or 42 per cent. of the total product of the Pennsylvania and New York oil regions since 1859, must now be placed in the list of thoroughly developed and declining fields. It seems quite certain that nothing but the discovery of a lower oil-sand horizon (a remote possibility) can check the gradual decline which has now set in, and which, no doubt, will become more apparent during the coming winter months, after the stimulating effects of heavy torpedoing have worked off.

But it must not be supposed that the oil of the Bradford district is exhausted. Many millions of barrels will yet be brought to the surface by these thousands of small but lasting wells, and the indications are that it will be a long time

before any other district in the State will come forward with an annual output greater than this remarkably tenacious field.

The following facts from the *Petroleum Age* and *Derrick Hand Book* are of interest here:

In 1875 the Bradford district came into public notice. Some small wells had been producing since 1868, but in 1875 seven wells were drilled, with a total production of 25,000 barrels.

In August, 1881, the Bradford district reached its maximum, making a daily average for that month of 80,838 barrels. Up to that time 11,683 wells had been drilled.

Oct., 1883, daily average, 35,654 barrels; 13,880 wells drilled.

Oct., 1885, daily average, 30,180 barrels; 14,981 wells drilled.

Decline of daily average in two years, 5,474 barrels.

New wells drilled meantime, 1,101.

The number of wells drilled, producing, and dry or abandoned, are estimated as follows:

1881. Sept. 1, 11,683 wells drilled; 483 abandoned; 11,-200 producing.

1883. Nov. 1, 13,880 wells drilled; 1,180 abandoned; 12,-700 producing.

1885. Nov. 1, 14,981 wells drilled; 1,346 abandoned; 13,-635 producing.

These figures make the daily average per well to be for August, 1881, 7¼ barrels; for October, 1883, 2⅘ barrels; for October, 1885, 2¼ barrels.

It may be truly said, then, that no material additions have been made to the "black sand" pools during the last two years. But little has been done, however, (as far as my knowledge extends,) in searching for the deeper black or brown sands which have been found at Sartwell, Smethport,* and in several wells in Elk county, as noted on Section No. 1 of the preceding chapter. These sands have given notable indications of oil and gas in several places, and are quite likely to furnish some areas of good oil pro-

*See Report of Progress R, p. 271, &c., and p. 291.

duction southwesterly from Bradford, when more intelligently sought for than they have yet been.

Whether the "Smethport-sand" and the "Elk county-sand" belong to the same geological horizon or not is as yet uncertain; for several layers of brown sand are reported in the wells of southern McKean and Elk. These wells were mostly drilled as "mysteries" by men of "practical experience" who were seeking an extension of the Bradford-sand and flattered themselves that they knew just at what depth it ought to lie. The upper rocks had no significance for them and no record was kept until the well had nearly reached the presumed proper depth. Then the drillings were watched until a brown sand or some semblance of it appeared; and this was the only fact which the drillers considered it necessary to obtain and record, to wit, the depth and thickness of the "Bradford oil sand."

The fruits of this dependence upon "practical experience" which views the oil-rock as a uniformly sloping plane, and disregards the unmistakable evidence of anticlinals, synclinals, and variations in geological structure are rather confusing. Some of the wells are thus made to record the "Bradford sand" two or three hundred feet above its proper horizon; others, from three to five hundred feet below it. If the records are reliable as to the sands noted, the only inference is that there are several beds of brown sand in the Elk county region.

Warren and Forest District.—This is the most northern of the "white sand" districts, and, unlike Bradford, whose production is principally confined to one sandstone (although it does occasionally produce some Second-sand and "slush" oil) its rocks are oil bearing in four or five distinct geological horizons.

Only one new detached pool (the Kinzua) has been discovered since our map was drawn, but considerable small-well territory has been added between Clarendon, Glade, and Wardwell, and also between Balltown and Cooper.

The Warren and Forest field seems to be ribbed with sandrocks and to have an undergound structure peculiar to itself. The Venango group is never seen there in any-

thing like its normal condition, and produces no oil except in one small well, (noted on the map,) about 3 miles south of Balltown, where the lower member of the group is said to be of a quality that promises better results than this well gives, when the time comes for systematic development.

The oil-producing rocks of this district lie from 300 to 1,050 feet below the Venango group, (see Section No. 1,) and seem to be somewhat restricted in their geographical range; for, to the north and west the wells seldom find any of these sands in a recognizable form; and sometimes, as in the case of Fagundus well, No. 37, and the Clapp, No. 45, before referred to, encounter nothing but slates and shales in the Warren and Forest oil-sand horizons. Northeastward, however, the sands are more persistent, although variable; and some of them seem to merge into the sandstones found above the Bradford oil-rock. Many unsuccessful ventures have been drilled in this region; nevertheless it seems highly probable that some isolated pools of oil will yet be discovered.

To the south-west, also, a great deal of drilling has been done in vain endeavors to connect this field with Clarion. But while many of these wells disclose traces of both the Clarion (Venango-Butler group) and the Warren oil-rocks, the only favorable results thus far have been one good gas-well at Marienville, in Forest county, (gas from the Clarion sands), and the discovery of a sand apparently corresponding with the Cherry Grove sand, which was at the forks of Wolf and Spring creeks, about 3 miles south-east of Byrom's Station, in Forest county. Here two or three small wells have been obtained, and as many dry-holes sunk. These wells, however, are all in a small area, so that there is plenty of room in this wilderness for oil-pools of considerable size between the scattered dry-holes which, for the present, check developments there.

The Clarendon pool now covers a wide area, and may be said to have established a connection with the pools to the north of it. It is considered desirable territory to operate in; for, although the wells are small producers, they main-

tain their production with remarkable steadiness, and can bé drilled and managed very cheaply, while the risk of getting dry-holes is much less than in other parts of Warren county. The other pools, where exceptionally large wells were obtained, turned out unreliable, except within restricted lines, and brought profit only to a few who were fortunate in their locations, investments and expenditures.

The statistics of this district are so scattered and imperfect that it would be a tedious task to ascertain the total number of wells drilled, and the actual amount of oil produced in the whole district since its discovery. The *Petroleum Age* gives the following partial statements, which may serve to show the characteristics of the field:

Cherry Grove; opened in May, 1882. (See I[4], p. 366, &c.)

Total product 1882,	2,345,400 bbls.	
" " 1883,	755,512 "	
" " 1884,	264,942 "	
" " 1885, (10 mo. to Nov. 1st,)	113,030 "	
Total to Nov. 1st, 1885,	3,478,884 "	
Daily average October 1st, 1883,		1,312 bbls.
" " October 1st, 1885,		412 "
" " decrease in two years,		900 "

Cooper Tract; opened in October, 1882.

Total product 1882,	29,864 bbls.	
" " 1883,	1,095,558 "	
" " 1884,	1,004,849 "	
" " 1885, (10 mo. to Nov. 1st,)	296,493 "	
Total to Nov. 1st, 1885,	2,426,764 "	
Daily average October, 1883,		3,314 bbls.
" " October, 1885,		777 "
" " decrease in two years,		2,537

Balltown; opened in December, 1882.

Total product 1882,	2,700 bbls.	
" " 1883,	776,244 "	
" " 1884,	807,506 "	
" " 1885, (10 mo. to Nov. 1st),	280,555 "	
Total to Nov. 1st, 1885,	1,867,005 "	
Daily average October, 1883,		4,298 bbls.
" " October, 1885,		925 "
" " decrease in two years,		3,373 "

Wardwell Pool.

Daily average production	April, 1884,	. . . .	475	bbls.
" " "	August, 1884,	. . . .	6,483	"
" " "	April, 1885,	. . . .	527	"

Stowell's Petroleum Reporter gives the average daily production of the whole *Warren District :*

In October, 1883,	. . . .	10,065	bbls.
" " 1884,	. . . .	12,517	"
" " 1885,	. . . .	7,180	"

Decrease of daily production in two years, 2,885 barrels.

These figures show that the Warren and Forest district is also declining, notwithstanding the large number of wells that have been drilled there during the last two years ; and it would seem that a sufficient number of unsuccessful tests have been made to prove that nothing more can be expected from the Warren group of sands, within the limits of this district, except, perhaps, another small pool or two like those already depleted, which, at the best, could only furnish a few millions of barrels of oil.

The Venango-Butler District, in which may be included all the territory along the oil-belt, from Tidioute and Grand Valley on the north to Pittsburgh, on the south, has been a field of considerable activity during the last two years. A new development is still in progress (December, 1885,) in Eldred township, Warren county, where oil in paying quantities has been found in the Hosmer Run oil-sand, or First-sand of the Venango group. (See I[4], p. 250 and p. 268.) Other good wells are producing from the Third-sand in South-West township, near Pool No. 21 on the map ; and also along the south-westerly extension of Pool No. 20. None of these are of much importance, however, except as being significant of the fact that, even within the range of what has been considered thoroughly tested territory, it is possible, with the present methods of drilling, torpedoing, and cheaply pumping wells, to find many spots where small wells can be obtained and operated at a profit.

In these old districts hundreds of wells are now pumped in clusters, by what is known as the "Sucker-rod system,"

where one engine is made to pump five, ten, or even more wells, and one man attends them, at a cost of perhaps fifty dollars per month.* When wells are so worked the addition of one or two to a cluster makes no material enlargement of the expense account, and, therefore, it is good policy to put down new wells near old ones whenever there is a prospect of getting even one or two barrels a day. With shallow drilling and cheap second-hand machinery the wells cost but little, and, prudently managed, make very gratifying returns for the investment. Scarcely an old well in the region would pay the cost of pumping if managed as wells were ten years ago. Then some slight mismanagement of a small well might result in its yielding water instead of oil, and it was likely to be abandoned after a few days of expensive and fruitless efforts to reclaim it. But now, as the dropping of one well from a cluster makes no material difference in running expenses, the walking-beam is kept in motion, and not infrequently the well is resuscitated after a few weeks and continues to produce oil for years. Many wells can be pointed out which are over fifteen years old,

---

*The method of pumping wells by "Sucker-rod" connection is this: A wheel eight or ten feet in diameter is placed in a horizontal position at the "engine well," and by a pitman caused to have an oscillating motion of about one foot. From a pivotal point on the rim of the wheel a line of connected rods (old sucker-rods were first used, and hence the name,) is run to the well to be pumped, and joined to the pumping gear. The rods are suspended by cords from standards erected at intervals along the line, and swing freely without friction. When the propelling wheel is made to oscillate, an up and down motion is communicated to the pump-rod in the well. Several wells can be attached to the same wheel, and the rods may branch off in any direction. By a system of balancing—that is, by connecting the wells in pairs, so that one shall be on the up stroke while its auxiliary is on the down stroke, four or five wells can be pumped with about the same power required for one alone.

The Bradford deep wells are pumped in clusters by running steam pipes from a central boiler to the engines at the wells. Here the wells are pumped by heads—that is, once or twice a day and just long enough to take out the oil which collects meantime—and by this plan any well can be pumped whenever necessary, and as long as required, without regard to the others. The engines also furnish the means for drawing sucker-rods and tubing, whenever required. With rod connections the wells are pumped continuously, and as there are no engines at the derricks the sucker-rods and tubing must be drawn by horse-power whenever the wells are "overhauled." But many of these wells run steadily for two or three years without even a change of valves.

and yield steadily more oil now than they did five years ago.

Millions of barrels of oil have been added to the available products of the oil regions by these inexpensive methods of pumping. There are thousands of acres underlaid by partly depleted oil rocks, where not one well in ten would pay to pump alone. The oil is not exhausted (as I have attempted to show in I[s], page 262,) but the pressure is reduced, and oil moves very slowly. If the expenses of pumping are such that wells producing only two or three barrels per day must be abandoned, then all the oil remaining in the rock is practically lost. But if these small wells can be kept at work they last for years ; and, as experience proves, they are capable of producing each from 3,000 to 8,000 barrels of oil, which, however, can only be drawn out slowly by persistent pumping, often continued for months after the yield has fallen below half a barrel per day.

This method of pumping is also an important promoter of development. It not only incites those who already have wells in operation to reach out and try to increase their production, (and they sometimes run their connecting rods a mile from the engine house,) but it gives others courage to drill in shallow territory which they otherwise would not undertake ; for, they now know that if only a small well is obtained it can be made remunerative by sinking two or three more near to it, so as to increase the output and bear a portion of the running expenses.

During the last three or four years a good deal of prospecting has been going on in a quiet way in the *Butler-Clarion field* ; but nothing to occasion any unusual excitement was discovered until the latter part of August, 1884, when the Phillips well at Thorn creek, coming in with an astonishing flow, just at a time when wild-catters began to despair of finding new fields at the north, caused a rush in this direction and started the drill again with renewed energy.

The Butler belt, as traced and developed ten years ago by degree lines beyond which no self-confident operator would venture, has been materially widened since that time in many places by additions of prolific spurs and pockets. We have not the data at command to note these accessions in detail, but if the productive field could now be accurately mapped, it would be seen that the popular belt-line-theory of that time condemned much valuable territory which is now rewarding those who discard compass lines and intelligently follow the drift of the oil rocks.

Only three new pools in this division of the field are noted on our map—Thorn Creek, Cogley Run, and Red Valley. They all receive their main flows of oil from the *Venango-Butler group of sands*, and have, or will have when fully developed, the characteristic history of the white-sand pools ; that is, a large flow from pioneer wells, inciting excessive drilling and a speedy outlining of productive area ; the attainment of maximum production in a few months ; and then a rapid decline which no number of new wells can permanently arrest.

Thorn creek is generally referred to as the "*phenomenal district*," on account of the enormous quantity of oil thrown out by some of its early wells. Armstrong well, No. 2, at first considered a dry-hole, upon being torpedoed (October 27th, 1884,) responded with terrific power,* and, according

*I quote the following from the *Derrick's Hand Book:*

"Those who stood at the brick school-house and telegraph offices in the Thorn Creek district to-day, and saw the Semple, Boyd & Armstrong, No. 2, torpedoed, gazed upon the grandest scene ever witnessed in oildom. When the shot took effect, and the barren rock, as if smitten by the rod of Moses, poured forth its torrent of oil, it was such a magnificent and awful spectacle that only a painter's brush or a poet's pencil could do it justice. Men familiar with the wonderful sights of the oil country were struck dumb with astonishment as they gazed upon this mighty display of nature's forces. There was no sudden reaction after the torpedo was exploded. A column of water rose eight or ten feet and then fell back again, and some minutes elapsed before the force of the explosion emptied the hole, and the burnt glycerine, mud and sand rushed up in the derrick in a black stream. The blackness gradually changed to yellow. Then, with a mighty roar, the gas burst forth. The noise was deafening. It was like the loosing of a thunderbolt. For a moment the

to reliable estimates, flowed 10,000 barrels of oil during the succeeding 24 hours. After the stream was turned into the tanks, hourly gauges (from 8 to 9, A. M.,) showed on the 28th. 400 barrels an hour; 29th, 260 barrels; 30th, 230 barrels; 31st, 210 barrels. On the second of December, 36 days after its opening, it was reported at 24 barrels an hour, and three hours afterward stopped flowing.* It was resuscitated, however, and flowed with declining strength for some time, when it had to be tubed and pumped. The history of Thorn creek was foreshadowed by the actions of this well. Its production swelled rapidly, and then as quickly dwindled away. At one year old it had become almost a deserted field as far as new work was concerned, and its gross daily production from 170 wells then completed did not equal the first four hours' flow of Armstrong, No. 2.

The commencement, culmination and decline of produc-

**Derrick Hand Book of Petroleum.*

cloud of gas hid the derrick from sight, and then, as it cleared away, a solid golden column, half a foot in diameter, shot from the derrick floor eighty feet through the air, till it broke in fragments on the crown pulley and fell in a shower of yellow rain for rods around. For over an hour that grand column of oil, rushing swifter than any torrent, and straight as a mountain pine, united derrick floor and top. In a few moments the ground around the derrick was covered inches deep with petroleum; the branches of the oak trees were like huge yellow plumes, and a stream as large as a man's body ran down the hill to the road, where it filled the space beneath the small bridge at that place, and, continuing down the hill through the woods beyond, spread out upon the flats where the Johnson well stands. In two hours these flats were covered with a flood of oil; the hill-side was as if a yellow freshet had passed over it; heavy clouds of gas, almost obscuring the derrick, hung low in the woods, and still that mighty rush of oil continued. Those who had at first estimated it at 50, 150, or 200 barrels an hour, raised their figures to 300 or 400, and some to 500 an hour. Dams were built across the stream that its production might be estimated, and the dams overflowed and were swept away before they could be completed. Where it swept the flats, a couple of boards were set up on edge, and the stream turned between them, and it filled the space and ran over the sides. People living along Thorn creek packed up their household goods and fled to the hill-sides. The pump-station, a mile and a half down the creek from the well, had to extinguish its fires that night on account of the gas and oil, and all fires around the district were put out. It was literally a flood of oil. There is no one now who saw it but that estimates the well made over 500 barrels an hour from two o'clock till four; and that it made over 8,000, some say 10,000 barrels the first twenty-four hours after being shot. It was as if the whole production of the Allegheny field was pouring out of a single well and flowing down the hill-side."

tion in the Thorn Creek pool are graphically shown in the following figures copied from the *Petroleum Age*:

*Sept. 1, 1884,	1 well;	production,	360 bbls.	per day.
Sept. 15, "	1 "	"	1,800 "	"
Oct. 1, "	1 "	"	2,592 "	"
Oct. 15, "	2 "	"	6,696 "	"
Nov. 1, "	6 "	"	9,264 "	"
Nov. 15, "	18 "	"	15,445 "	"
Dec. 15, "	31 "	"	10,972 "	"
Dec. 31, "	40 "	"	8,350 "	"
Jan. 30, 1885,	51 "	"	6,688 "	"
Feb. 28, "	63 "	"	7,341 "	"
Mch. 28, "	77 "	"	5,875 "	"
April 25, "	100 "	"	8,682 "	"
May 30, "	124 "	"	8,884 "	"
June 27, "	148 "	"	4,034 "	"
July 18, "	156 "	"	2,959 "	"

The average daily pipe-line runs from the Baldridge district, which includes Thorn creek, are reported as follows:

April, 1884,	844 bbls.
May, "	1,061 "
June, "	969 "
July, "	889 "
August, "	843 "
Sept., "	2,644 "
Oct., "	6,034 "
Nov., "	9,493 "
Dec., "	8,730 "
Jan., 1885,	6,199 "
Feb., "	7,349 "
March, "	7,239 "
April, "	9,333 "
May, "	7,488 "
June, "	5,905 "
July, "	3,856 "
August, "	2,268 "
Sept., "	2,021 "
Oct., "	1,898 "

It will be noticed that the Baldridge district was making 843 barrels a day before Thorn creek was added, September, 1884. Some new wells have been drilled in Baldridge, and probably it has maintained an average daily production of 700 barrels. The total pipe-line runs from Baldridge and Thorn creek from September 1, 1884, to November 1, 1885,

*This was Phillips well, No. 1, which struck sand August 29, 1884, and increased largely as it was drilled deeper from time to time.

foot up 2,442,804 barrels. Deducting from this the estimated production of Baldridge, 700 barrels per day for 426 days, = 298,200 barrels, and we have 2,144,604 barrels to represent the total output of the Thorn creek field from its discovery, September 1, 1884, to November 1, 1885.

No doubt the Phillips well* on Oil creek produced, during its lifetime, more than half the quantity of oil so far taken out of this "phenomenal pool" by about 170 wells, and it is quite improbable that Thorn creek could have claimed the distinction of having furnished the largest wells in the country, if the Oil Creek wells had been drilled of as large diameter and had been dry cased as wells are now.

Cogley Run and Red Valley are still under the drill, the former having apparently passed its prime, the latter yet developing, and showing, at the expense of some of the operators, the variability of the oil sands in these middle grounds between the Venango and Clarion bèlts, where other pools undoubtedly await the fortunate discoverer.

South-westerly and southerly from Thorn creek, the prospector has been actively at work for some time, but so many conflicting reports about the findings in the wells have been circulated for the purpose of confusing outsiders that even the owners themselves cannot now furnish trustworthy records of them if they desired to do so. The Mt. Nebo well, in Ohio township, Beaver county, is said to have found the Thorn Creek-sand, and it undoubtedly produced some oil, but, not meeting the expectations of its owners as a flower of the first magnitude, it was subjected to so many ill-advised experiments to improve its capacity that it finally refused to yield anything. It seems to have given notice, however, of the presence of the Thorn Creek oil rock in that

*See I[2], p. 54, where this well is credited with 600,000 barrels. This statement was given to Mr. Nettleton in 1869, when the well was still pumping. I am reliably informed, however, by one who shipped a large part of the oil, that this estimate comes from the books of parties who had a certain share in the well, and kept an account only of the oil handled by them. He is confident that the other owner's and the land interest's oil would swell the figures to over 1,200,000 barrels.

locality, and the results of future drilling in the neighborhood will be awaited with interest.

On the Ohio river, near Rochester, some wells drilled for gas are reported to be making good shows for oil, but if the depths given are correct, the oil cannot come from the Thorn Creek sand. It will probably be found to be the same as that in the old Rochester Tumbler Company's well, (I^3, p. 279,) and is not likely to be of sufficient importance to materially affect the gross output of the oil regions.

"Little Washington," in Washington county, is the only new oil field remaining to be noted on our map. Its first oil well, the Gantz, was struck on the 1st of January, 1885, but was not put in working order until several weeks later; proving to be only a moderate producer, developments lagged, and, up to the 1st of November, only two other *oil* wells had been drilled—the Gordon, making about 100 barrels a day, and the Gabby, showing some oil, but not then tested. The three spots on the map give the location of these wells.

Washington county developments have had rather a curious history since their commencement in 1881. After six or eight wells had been drilled for oil in Mount Pleasant and Cross Creek townships and obtained nothing but gas, the citizens of "Little Washington" concluded to drill near their borough for gas for heating and lighting purposes. The first two wells were successful and the drill stopped in the gas sand about 1,800 feet below the Pittsburgh coal. A rival gas company was formed, but their first well, the Gantz, instead of venting gas, filled up with oil, and started an oil excitement which soon placed all the contiguous country under lease for oil purposes. The first oil well located was supposed to be some distance from the gas streak and on a sure line for oil, but it came in a large gasser and was sold by its disappointed owner to the People's Heat and Light Company. Meantime this company

had completed two new gas wells on the northeasterly extension of their anticlinal gas belt, and located another on the southwesterly extension of it, perhaps 150 rods from their No. 1. This well, the Gordon, upon reaching the gas-sand, found oil; but as it did not appear to be in large quantity and the company wanted gas and not oil, the drill was urged deeper in hopes of finding the sand which yields the large and lasting flow of gas in the McGuigan well in Mount Pleasant township, about 9 miles to the north-west. Up to this time nothing was known practically of the measures below the 1,800 foot gas sand at Washington, for the drill had never penetrated them. After drilling about 260 feet the seekers for gas were surprised to find the hole filling up with oil. With deeper drilling the well made frequent flows, and after being put in pumping order produced about 100 barrels per day without torpedoing.

This started the oil fever anew, based on the prospect of a newly discovered and more prolific oil horizon. New rigs were immediately started near the Gordon, and options secured wherever possible near the Gabby well, a mile or more towards the south, which already had some oil in the hole from the Gantz sand struck at 2,294 feet and stood ready to drill down to the Gordon sand. Delayed by accidents and the slow drilling incident to such deep wells, the Gabby is still drilling, but is supposed to have passed below the Gordon sand without broaching oil. The failure of this well leaves operators still without any positive clew as to the trend of the oil streak or the extent of territory that is likely to prove productive and they are now awaiting the completion of some of the new wells commenced under the last excitement.

With our present information, it is too early yet to venture a positive opinion upon the probable extent and productiveness of this new field, but, considering the irregularities of geological structure shown by the wells already drilled, and the variability of the gas and oil horizons, we may infer that it will not be an oil field unspotted by dry holes. Many good wells will, undoubtedly, be found here and probably scattered over quite a large area, but deep

and expensive drilling is likely to prevent rapid development and excessive crowding of wells, in which case there is little fear of its flooding the market with oil, like some of the comparatively shallow and less expensively operated districts at the north.

The *Dunkard Creek district*, of Greene county, has received some attention from the oil operator during the last summer. Six or seven wells have been drilled, only two of which are known to be productive in the so-called Second-sand. Here, as elsewhere, well drilling is mystified, and it is supposed that the two wells referred to are capable of making a great deal more oil than they are now showing, when the owners choose to put them in proper working order. However this may be, oil developments in this field, since 1862, have been little better than a series of disappointments and disasters to those who have engaged in them. It may be that improved methods of drilling and management will prevent some of the troublesome accidents from caving, &c., which are said to have ruined so many of the early wells, but the most serious obstacles in the way of profitable operations—irregular oil-sands and restricted oil deposits—still remain. Present operators are working much more intelligently than those who pioneered the field, supposing they were drilling in the First, Second, and Third-sands of Oil creek; but while a knowledge of the age of the rocks and their characteristics in other places where they have produced some oil may enable them to work with less risk of failure, it can hardly assure them uninterrupted success. Few wells in this region have been drilled deeper than 600 feet below the Pittsburgh coal. Down to this point, it is demonstrated that the rocks are only oil-producing in spots. Some good and lasting wells have been obtained, but eight or ten dry holes have been drilled in the district for every good well secured.

The most important questions as to the future possibilities of the field now depend for their solution upon the revelations of the drill when sunk 1,200 feet or more into the

locally untested rocks below these shallow oil horizons, and, fortunately, these questions will not long remain unanswered, for, under the impetus given by Washington county successes, one or two wells are already drilling in search of deeper sands.

Chapter III.

On the relations of gas to oil.

Gas and oil are so intimately related that an oil-field must necessarily be a gas-field. From one end of the oil belt to the other, gas has been found in larger or smaller quantities in every oil well drilled. But the conditions under which it exists are quite variable. Sometimes large flows issue from sandstones lying above the oil-producing rocks, sometimes from the oil-sand and with the oil, and in other cases it may be from sands below the oil horizons. "Gas streaks," as they are popularly called, or areas where the rock contains more gas than oil, are common throughout the oil regions, skirting the edges of good territory in some places, or streaking the central portions of it in others.

It does not follow, however, that every gas well must produce oil, for even within defined oil fields there have been gas wells that made no oil beyond a slight condensation in the delivery pipes; and elsewhere gas-producing rocks are sometimes absolutely barren of oil in the gas horizons.

Hence, to attempt to locate with exactness upon our map all the spots in the oil-belt that have produced notable quantities of gas since oil developments commenced, would be a fruitless and almost an impossible task. It will be quite sufficient for the purposes of this report if we let the oil pools stand as they are, and view them as representing gas pools also, and fill out the draft by adding other pools in a different color, to designate those which produce gas almost exclusively.

To note all the points where gas has been found outside of the oil belt would be to locate nearly every wild-cat well in the country, for they all have produced some gas, and many of them in valuable quantities, if it could have been utilized in the neighborhood. We have only spotted those places where exceptionally large wells have been obtained,

or where the gas has actually been used for heating and lighting purposes.

In Potter county one spot is colored. At Shingle House the gas is of sufficient importance to be piped to consumers. Several other places in the north-western portion of the county have furnished gas wells, but not having visited that section in several years, I cannot venture to locate them. In the south-western townships six or eight deep wells have been drilled which give very little encouragement to continue prospecting there for either gas or oil. East of Potter county I am not aware that any remarkable gas wells have been found.

The Allegany oil district has produced an immense flow of gas which is still being utilized throughout the field, and is likewise piped to Olean, Cuba, Friendship, and Wellsville.

The Bradford district has also been very prolific in gas, but unrestricted consumption and waste have very materially reduced its pressure and volume. At first the town of Bradford had an ample supply from wells near the city and on the north-westerly edge of the oil-field; but this failing, pipes were run to the Rixford gas pool, (the spot is left blank upon the map,) which re-inforced the supply for some time. Later, however, it became necessary to lay a new line, of over twenty miles, to connect with the Wilcox gas pool near the southerly line of McKean county, where there is a large deposit, capable, no doubt, of responding to all demands that can be made upon it for many years to come. The Wilcox wells (R, p. 148, &c., and I[4], p. 104, &c.) have also produced some oil in what is considered to be the equivalent of the Bradford-sand; but not enough to make them remunerative as oil wells. The oil-sand lies here about 20 feet below ocean level, and more than 400 feet lower than at Bradford.

The Sargeant pool, in the same horizon as the Wilcox, is noted for its Geyser well, described in Report R, p. 244, &c. Its gas was wasted and the well is now spoiled by water.

The Watson well at Johnsonburg station, in Elk county,

ejects a large volume of gas from a brown sand at 1,660 feet, and indicates the presence of a good pool in that vicinity. The gas was allowed to waste two or three years, but is now being used for heating and lighting purposes. A well near Grant & Horton's tannery, at Ridgway, also flowed some gas at 905 feet, but was not materially improved by deeper drilling.

Wells at Kane City, supplying the town with heat and light, and at Wetmore, demonstrate that there is an abundance of gas to be had there by drilling for it, and even in this region of forests it is found cheaper to use gas than wood for fuel.

The Roy & Archer gas-pool, in the north-eastern corner of Elk county, has three wells, one of which furnishes more than enough gas-fuel to run a large establishment for making wood-acid and charcoal from the beech, maple, and other hard woods which abound in that locality. This pool is remarkable from the fact that the gas (and the wells, also, had favorable indications of oil) apparently comes from a lower geological horizon than any other known to be productive in the Pennsylvania oil regions, from a brown sand which lies stratigraphically more than 1,800 feet below the horizon of the Murraysville, Westmoreland county, gas-sand. (See Section 1.)

The great Sheffield gas-pool extending across the Warren-McKean county line is one of the largest and most prolific known in the country. It was discovered in 1875 by the Hague or Sheffield well, which is still flowing strongly, the gas being piped to Sheffield. This well has a remarkable history on account of the troubles encountered by the formation of ice in the hole.*

*See I^2, p. 193, and I^4, p. 379. Another curious freak not mentioned in the pages referred to was this: After the two-inch tubing had been put in to test the well for oil, it was partly filled with water to buoy up the sucker-rods while being inserted, and lighten the labor of putting them in. When about two thirds of the rods had been lowered, some obstruction was met, and, after ineffectual attempts to force them further, it was concluded that the tubing was imperfect and would have to be withdrawn. Preparations were made to pull the rods, but, on attempting to run them up, they were found to be immovable. Hence, rods and tubing had to be taken out together, a very diffi-

A number of new wells have been sunk in this district during the last two years, and the product is now piped to Warren and to Jamestown, New York, a distance of 32 miles.

At Barnesville, or Old Sheffield, a large gas well was obtained in 1879 in a rock one hundred feet or more above the Hague well sand. (See I^4, p. 24.) This has been utilized for a long time in making lamp-black.

The Cornen gas pool, lying between Clarendon and Cherry Grove, furnishes strong and lasting wells. The gas is piped to Clarendon and Warren.

This region abounds in gas, both in and out of the oil pools, and, as it is not confined to any one particular horizon, an unlimited supply for all purposes to which it can possibly be applied seems to be assured for many years.

In the city of Erie, and, in fact, almost anywhere along the Lake Shore in Pennsylvania, gas-wells are obtained by drilling from 600 to 800 feet, but they are of low pressure and small volume as compared with wells in the oil regions. The gas seems to be diffused through beds of interstratified sandstone and sandy shale, capable of storing large quantities, but, having little pressure, it issues slowly and flows with remarkable constancy a long time. The Erie wells have been referred to in Report L, page 168, &c., and the same is copied in Report I^4, p. 121, &c. Since these publications were issued many wells have been drilled, but they reveal nothing new that requires to be specially mentioned here.

In the Venango district, a great many large gas-wells have been found, most of them in early times, when they were considered of little or no value. Abandoned, set on fire,

---

cult and undesirable job, as any one knows who has been forced to undertake it. When the lower joints of sucker-rods and working-valve were reached, they were seen to be solidly frozen in the tubing. The water at and near the point where gas came into the well had frozen, the ice-core stopped the rods in their downward passage, and, while endeavoring to force the obstruction, new ice set around the valve and rods and held them firmly. These phenomena were considered remarkable at the time, but since then several wells in the Cooper district have been in like manner seriously embarrassed by ice both in drilling and sand-pumping.

and left to care for themselves, they, in a few years, either died from exhaustion or were drowned by accumulations of water in the hole. Old "burning well" sites can be pointed out in every part of this country.

One well, however, the Newton, located in Oil Creek township, Crawford county, about five and one half miles north-east of Titusville, (I^3, p. 198,) was put to practical use as early as 1872, by the laying of a gas main to connect it with the city. This seems to have been the first attempt at piping gas any considerable distance for fuel and light. Other wells have since been put down in the Newton neighborhood, but the original supply of gas could never be increased or even sustained, and now the yield of the pool barely meets the requirements of a few families.

The Venango group has been so thoroughly ventilated by oil wells in northern Venango, Crawford, and Warren counties that no large, permanent flows of gas can now be expected from it, and hitherto no indications of prolific gas deposits at lower geological levels have been noticed in any of the deep wells drilled north-west of the Allegheny river. But south and east of the river the group has not been so completely relieved, although an enormous quantity of gas has been wasted, as at Gas City, East Sandy, (see L, p. 166 and p. 177,) and other places. The possible gas supply of this section is also immeasurably increased by the recent discovery of a rich deposit in a sand belonging to the Warren group, and lying about 900 feet below the Venango group. The first notice of this sand was given early in 1885, by a well on the Speechley farm in Cranberry township, and now several wells in the vicinity are yielding largely, the product being piped to Oil City, thence up Oil creek to Titusville and the towns along the route. It is also sent southerly in sufficient quantity to satisfy the wants of those engaged in oil developments at Cogley Run and Red Valley.

The old Butler and Clarion oil-fields also had many extraordinary gas wells within their limits. Some of the most noted, the Fairview, Burns, and Delameter, are referred to in Report L, appendices B, C, D, and E, and the Thompson, at Carbon Center, in V, page 170.

Wells drilled east of the Clarion belt show considerable gas in all cases, and no doubt good deposits will yet be discovered there. For the want of precise information, I am unable to locate more than two gas spots in this part of Clarion county—one on Cherry run, in Toby township, where a very strong gas-well was obtained in 1878 (I^4, p. 412) which burned for several years; the other near Strattonville, in Clarion township.

At Brookville, Jefferson county, two wells have been drilled, but the gas-flow being insufficient for the purposes required, another will shortly be sunk.

At Canoe creek, in North Mahoning township, Indiana county, the Snyder well struck strong gas in 1883, which is piped about five miles to Punxsutawney. Reported depth to gas-sand 2,615 feet. "Sand 65 feet thick, black, fine, and hard." This sand evidently lies far below the gas horizons of the Allegheny river region.

West of the Venango and Butler-belts gas deposits are of frequent occurrence, and in the north-western part of Butler county the First oil-sand is eminently a gas-producing rock. Near Harrisville and Centerville, in Mercer and Slippery Rock townships, no well fails to find gas. The Wolf Creek and McMurray's Mill wells, described in report V, pages 100 and 132, would no doubt have been profitable investments if there had been any market for their gas. But only within the last year have plans been perfected for making these gas deposits available. A pipe line is now being laid from the Centerville district to New Castle and several wells have been drilled which give assurance of ample supplies. In the Harrisville district large tracts of land have been leased by the Natural Gas Company of Youngstown, Ohio. One good well has been completed there, and after further development it is proposed to pipe the product about thirty miles to Youngstown. The pressure and volume of gas in the wells on this range of territory do not seem to be as great as in the deeper wells at the south, but the gas-sand is of good quality and thickness and underlies an extensive area; hence it may be expected to yield in the aggregate quite as much gas as some of the more pretentious fields.

Central Armstrong county abounds in gas, as shown by numerous wells. A test for oil at the mouth of Pine creek, in 1877, (I[a], p. 409,) found only gas and was abandoned. Two or three wells just north of Kittanning furnish the town with heat and light, and others three miles west, in Franklin township, send in plenty of gas fuel to the iron manufacturers. When these pools shall fail, no doubt others will be found within easy reach, for no town in the gas-regions appears to be more favorably located than Kittanning for obtaining convenient and lasting supplies.

When Report L was being prepared in the fall of 1875, the gas wells at Lardintown, Saxon Station, Freeport, Leechburg, and Apollo were in their prime, and beyond them to the south-west no promising deposits of gas were known. The characteristics of the wells then producing, the initial experiments at piping gas long distances, and its application to iron-working are so fully discussed in appendices B, C, D, and E that they require no further notice here. The pipe line from Lardintown is still working successfully, but, for a year or more, the old Harvey well has not contributed any gas to it, having gradually weakened in power and succumbed to accumulations of water. Twelve additional wells have been drilled, some obtaining gas in the "First-sand" horizon and some about 500 feet lower, in the "Fourth-sand." Seven of these have been abandoned, leaving five connected with the pipe, and these altogether are probably not furnishing as large a quantity of gas as the Harvey well alone produced ten years ago.

The Saxon Station well has been utilized for making lampblack, and, standing alone, still flows with considerable volume.

At Freeport and Leechburg, ten or twelve wells have been put down, but all are of moderate capacity. The old Leechburg well still produces some gas. The Apollo wells are all small.

Three miles south-westerly from Apollo, the Pine Run well, in Washington township, failing to get either gas or water in the Murraysville-Leechburg sand, drilled on about 125 feet below it to another sand, and got a very good flow

of gas. This was in January last, and since then, several wells at Apollo and Leechburg have been deepened, in some cases with improvement, but not to the extent anticipated.

About three miles south-east of Pine Run well is the old Beaver Valley well, completed in 1878, a few days before the first well (Haymaker No. 1) at Murraysville, nine miles south-west, and claimed by Mr. Mehaffey, one of its owners, to have been quite as large a gasser. As no oil was obtained, the well was abandoned without casing. The derrick was afterwards burnt, but the roaring gas and rising column of fire and water still marked the spot. For eight years this struggle between gas and water has gone on, and still the gas maintains sufficient power to lift the column spasmodically and to sustain a continuous gas flow, which makes a flame about 15 feet high. This well is not far from the axis of the Murraysville-Roaring Run anticlinal, on which, about two miles and a half to the north-east, and exactly in the mouth of Roaring run, a deep well was sunk in the spring of 1885, which found no gas of value.

Here we have a good illustration of the uncertainties that must ever attend all operations for oil and gas. A large gas well (Beaver valley) on an anticlinal, in the Murraysville-Leechburg sand; a good gas well (Pine run) in a synclinal, where the Freeport upper coal is found 210 feet lower than at Beaver Valley well, but in a sand 125 feet deeper than the Leechburg sand; a dry hole on the anticlinal with no available gas in either of the gas horizons of the other wells, and all within a radius of less than two miles.

The Tarentum or Bull Creek gas-field, in the northwestern townships of Allegheny county, was first tapped by the well of Graff, Bennett & Co., in June, 1878, (I[3], p. 405,) but the value of the find was not appreciated until several years later, when, after three or four unsuccessful wells had been sunk near it and to the east, Messrs. Ford and Nelson ventured about a mile northwardly up Bull creek and brought in a large gas well in January, 1883, which started a development that has resulted in defining one of the most prolific and important gas pools of the country. Over twenty wells have been drilled by companies who own and operate

their own wells and pipe lines, and the supply is ample for the town of Tarentum, the large Plate Glass Works at Creighton, the Pennsylvania Salt Manufacturing Company at Natrona, the Paper Mills of Godfrey & Clark, and the Bottling Works of Richards & Hartley. The Philadelphia Company is also piping large quantities to Pittsburgh, (about twenty-two miles,) and the Hite Gas Company, having laid a ten-inch main to the city limits and being debarred from entering, are forced to allow their product to waste.

The Tarentum district is the most northerly one contributing to Pittsburgh. The others are Murraysville, on the east, in the westerly edge of Westmoreland county; Homewood, partly within the city limits, and Hickory, on the west, in Mount Pleasant and Cross Creek townships, Washington county. Cannonsburg, Washington county, and Montour, Allegheny county, will soon be added.

The fact seems to be clearly established that all of these derive their gases from the Venango-Butler group or from sandstones above it: Murraysville from the representative of the First-sand; Homewood and Cannonsburg from a higher horizon; Hickory from a lower—and also Jones and Laughlins' wells in the city and Homestead well six or eight miles up the Monongahela. Hickory and Cannonsburg also produce largely from the Homewood sandstone. These specific identifications, however, are provisional, for, as previously explained, the facts at command are as yet too meager to base positive deductions upon.

Murraysville may justly claim to be the "phenomenal" gas field of the country. On a narrow strip of territory about five miles long over thirty wells have been drilled—the most of them within the last year—without a single failure. The first well (Haymaker No. 1) was completed in 1878, and for five years its product, equivalent in heating power, probably, to 1,000 tons of coal per day, was allowed to waste. In 1883, other wells were drilled and a pipe line laid to East Liberty, Pittsburgh, to which this well was attached in November. In the same year another line was laid from the Lyons Run wells (a part of the Murraysville belt)

to the Edgar Thompson Steel Works near Braddock. Since then six or eight other mains of different capacities have been run from the district to Pittsburgh and McKeesport, and still much gas is going to waste. At present the Philadelphia Company controls all the outlets except one belonging to the People's Natural Gas Company, whose main is laid to the city limits and awaits permission to enter.

It would be interesting to know what effect the escape of so much gas has had upon the normal pressure in the Murraysville pool; but none of the wells here have been properly equipped for testing pressures. To confine the gas in these wells even to a pressure of 350 to 400 lbs. to the square inch would be a hazardous undertaking, for it might lift the casing and greatly damage the well. In the northern gas-fields, wells are cased and packed in such a manner that they can be controlled without danger. When the product of a well is not needed for a time, a gate is closed and the flow stopped. In the Wilcox district the pressure runs up to about 575 pounds to the square inch and then remains stationary. In the Allegany, New York, district it checks at about 400 pounds; while in some parts of Butler county it does not venture above 250 pounds.

The Murraysville wells are run under a safety valve pressure of from 150 to 200 lbs. as circumstances may require; and if the supply at that pressure is in excess of the demands of the delivery pipes, a waste lead allows the surplus to escape and burn at the wells. In this way hundreds of millions of cubic feet of gas have been wantonly consumed, when it should have been husbanded for future use. The popular fallacy that these southern gas fields are inexhaustible is responsible to a great degree for this improvident waste. With proper appliances the wells here could be controlled as readily as in any other district, even allowing that the pressure might run up to 1,200 pounds to the square inch, as some claim it is capable of doing. And until this is done we shall never know just what effect the multiplication of wells is having upon the resources of the pool—unless some remarkable decrease of production becomes plainly apparent—for all that now

can be learned is that, "the wells do not interfere with each other and are yielding as largely to-day as when first opened."

At Homewood, Twenty-first ward, Pittsburgh, a very strong gas well (Westinghouse No. 1) was struck in May, 1884. It gave promise of an immense yield; but some water accompanied the gas, and fearing it might eventually prove detrimental, efforts were made to case it off. While experimenting to this end the volume of gas decreased and ever since the well seems to have made a very unsatisfactory record. Fourteen holes have been drilled in the neighborhood of this well on the popular north-east south-west line, two of which are outside the city limits. All had a show of gas for a while, but only three or four of the most north-easterly ones appear to be profitable producers. One of the partial failures has been deepened, but how much and with what results cannot be learned.

The Hickory district was opened by the McGuigan well in March, 1882. The gas had extraordinary power and volume, but being so far from market, was allowed to waste for a year or more, when a six-inch main was laid to Birmingham, about 22 miles. In 1884 two other large wells were struck in the immediate vicinity of Hickory post office; but they are only about 1,060 feet deep, while the McGuigan is 2,237 feet. Hence there are two important gas horizons here, one probably in the Homewood sandstone, the other well down towards the bottom of the Venango-Butler group. Still later, two more wells were drilled and continued down to the McGuigan-sand. The supply of gas from these four wells is enormous and a pipe line has been laid to convey it to Pittsburgh.

The Cannonsburg field, as before stated, produces gas from two horizons. Three or four wells have been drilled, others are under way, and a pipe-line will soon connect it with the city.

At Washington five gas-wells have been drilled. They are fairly prolific, but altogether furnish hardly sufficient gas to supply the town.

The Bridgewater field, in Beaver county, gives promise

of great capacity and endurance. It was opened in the spring of 1884. Phillipsburg, Beaver, Rochester, New Brighton and Beaver Falls, are being supplied with gas from it, and it seems capable of responding to any other demands that may be made upon it.

The old Fetterman well, spotted above Beaver Falls, and referred to in Report I^4, page 142, seems to have been a large gas-producer in 1863, but wells since drilled in that vicinity have not proved very prolific.

Two wells at Bellevernon, Fayette county, are yielding a moderate flow of gas from a sand lying considerably below the Pittsburgh salt-water sand. Its exact horizon cannot be stated until the records of the wells are obtained.

These facts are given merely as explanatory notes to the map. Just now every interest connected with the production, transportation and consumption of natural gas is rapidly expanding. New fields are being eagerly prospected; new wells are almost daily completed; new pipe-lines projected, and old ones enlarged and extended; the developments on every hand are so rapid and important that definite outlines of gas-pools and exact descriptions of gas-plants become obsolete even while being prepared and published.

Chapter IV.

Theories of oil and gas.

In the Fourth Annual Report of the United States Geological Survey, 1882–83, Mr. Albert Williams, Jr., has the following introductory to an article, entitled "Popular Fallacies Regarding Precious-Metal Deposits:"

"The tendency to generalize from incomplete data is a failing to which the practical miner, in common with the theorist, must sometimes plead guilty. The latter is often too ready to formulate a law from a narrow range of observation; too prompt in offering an explanation for each new phenomena. The former, whose work brings him in contact with varied occurrences in nature, rightly enough forms his conceptions and expectations from what he has seen and knows—and he is indeed a keen observer—but often reasons from too limited a base-line. On the one hand, the study of mineral deposits has been clogged by a mass of premature hypotheses; on the other, the search for and development of mines often have been conducted under the bias of preconceived prejudice. Besides the unconscious and ineradicable reliance on *a priori* methods and doubtful analogies, there is another important source of error which is common to all branches of inquiry. Some one puts forth a suggestion; it may be the sheerest piece of guess-work, but it finds its way into print, floats with the current literature of the subject, and by virtue of iteration, becomes accepted as fact without perhaps ever having been seriously scrutinized. These are the causes which explain most of the popular misconceptions that have gained circulation regarding precious-metal deposits."

"The work of the mining geologist in large part consists in demolition; in clearing away the rubbish of overthrown errors to obtain foundation room on which slowly to build a sound structure; in sifting and weighing a mass of spec-

ulations in the search for material. On the practical side, the progressive miner learns that the features of a single district or of a few localities may not be an unfailing index to the characters of all other deposits; but he is at times hampered by established prejudices which have all the weight of precedents. Fortunately the spirit of modern investigation tends rather to the collection of facts than to speculation. It is now understood that, given sufficient data, the laws evolve themselves; and that the reversal of the logical sequence, putting the theory first and then searching for facts to fit it, tends only to hopeless perplexity."

These remarks are as pertinent to mining for oil and gas as they are to mining for precious metals. The petroleum industry has its "practical miners" and its "theorists," its misleading "current literature" and its sanguine operators, prone to accept and act upon almost any attractive hypothesis without "seriously scrutinizing" it.

Ever since the first oil well was struck, oil producers have been unreasoningly following popular theories, having very little if any foundation in fact. In applying these theories to practice, a study of the surface indications only was deemed needful, and the much more important teachings of the drill, were, until quite recently, almost entirely ignored.

At first, well sinkers clung tenaciously to the valleys, because they had a theory that the streams flowed in chasms rent by upheavals and crackings of the earth-crust, and that oil-leads followed the lines of such fissures.

Then, after some petroleum seeker had experimentally located a well upon a hill, and, contrary to the predictions of theorists obtained a large flow of oil, a *ridge theory* came into favor. It was now argued that the hills had been uplifted, and oil and gas, seeking the higher levels, should be more plentiful on ridges than in valleys. This theory is still quietly held by some experienced operators, and the results of it may be seen from Allegany county, New York, to Pittsburgh, in the numerous wells—a great majority of them dry—that dot the dividing ridges between north-flowing and south-flowing streams.

A third theory adopted for its surface indications, the deer-licks and boggy-springs which follow the outcrops of the pebbly conglomerate rocks. The *conglomerate* has probably incited more wild-catting than any other surface indication; and it is entitled to the credit of having led to many new developments; not because it is itself in any way an index to oil—for as a definite locator it has no significance whatever—but because its supposed relations to the oil rocks according to this theory gave prospectors courage to drill wherever such rock was seen or might be found, whether in New York or in Kentucky; and the hundreds of wells sunk in consequence of its presence in locations that otherwise would have been neglected have accidentally brought forth some good results.

A fourth theory may be called the theory of spiritualism or magic. Dreams and the divining-rod in all its various forms have always had, and strange to say continue still to have, their votaries among oil producers. Successful locations, in fact, have been occasionally made under this guidance; for inside the limits of the oil regions, even haphazard locations must sometimes succeed. But the followers of spiritual or magical rites have averaged more failures and sunk more money for their friends and for themselves than any other class of operators in the country; and it is a fact well worthy of attention that not one instance is recorded where a well located by any of these mysterious agencies tapped the richest part of an oil pool. Professing to be able to follow narrow oil-leads for miles, to locate cross veins with absolute accuracy, and to map out all the intricacies of the oil rocks, the advocates of this method fail in practice to secure even the average share of success which falls to the lot of the uninitiated.

A fifth—*the belt-line theory*—has for many years overshadowed all others, and still to a great extent holds its sway over the majority of minds. But it has been gradually modified so as to become merely an adjunct to the *pool theory* for oil and the *anticlinal theory* for gas. When unconfined by arbitrary compass lines and intelligently employed in connection with the facts developed by the

drill, it is unquestionably of some assistance in tracing out an oil field, and for the following reasons: The general lines of geological structure in this part of the Appalachian basin run approximately north-east and south-west; its sand beds are elongated in that direction; they come in at different horizons, not always one exactly over another, but the higher ones overlapping towards the north-west, as if marking the trend of old currents and old shore lines; its shale beds and red rocks have a similar structure; its anticlinals also take the same general direction—therefore a belt-line judiciously followed in harmony with these prevailing lines of structure keeps the operator on a range of country containing the maximum possibilities of success.

A sixth—*the pool theory*—claims that the oil-bearing rocks were deposited in detached patches, of greater or less extent, and not in long, narrow, continuous ribbons, as claimed by thorough-going belt-liners. This theory is now in favor with prospectors both for oil and for gas. In 1880, when it had few adherents, Chapter 25 of Report I[3] was written for the purpose of directing thoughtful criticism of it. A reference to that publication will make further discussion of it here unnecessary.

Seventh—*the Anticlinal theory*—that gas-wells should always be located on anticlinals, and not in synclinals, because gas is lighter than water or oil, and should seek the highest reservoirs, premises a permeable sand-rock containing water, oil and gas, or only water and gas in such proportions, and under such conditions, that the fluids may stratify themselves as freely and completely as they would do in an open tank under air, the water and oil at the lower levels and gas at the higher.

There is nothing new in the theory, as many suppose, for it has been long ago discussed and illustrated in text-books on geology and in nearly every book published relating to the production of petroleum. Well-locators, however, gave it but little attention until developments intended exclusively for natural gas commenced.

Wherever the proper conditions exist there seems to be no objection to accepting an anticlinal as one of the factors

in locating gas-wells; but, in most cases, it is being too inconsiderately used, without giving due thought to other and much more important considerations.

First, it is proven by the experiences of over 25 years that no profitable oil or gas-well can be obtained in the Upper Devonian strata and rocks of later ages in the Pennsylvania oil-fields unless a good sand-rock reservoir is found. Second, it is a generally accepted conclusion that the oil and gas-making material was deposited before—and, perhaps, in some cases with—the producing sand-rock, not after it; that the tendency of gas and oil when generated is upward, not downward. Therefore, the two primary conditions to be sought are gas-producing materials and sand-rock reservoirs to hold the products. All others are secondary, for, without these, no profitable oil or gas-wells can be had.

Now, what has an anticlinal to do with these indispensable qualifications? Evidently nothing, in a primary sense, for it had no existence when they were being prepared. Nevertheless, I have heard experienced operators, self-confident in their geological acquirements, assert that certain oil-fields could not extend beyond fixed limits on account of anticlinals which interrupted the deposition of the oil-sands when they were forming.

It is well known that all our oil rocks are sedimentary; that they are composed of materials derived from older rocks, the disintegrated particles of which have been sifted, assorted, and deposited in stratified layers by the action of water. These rocks are known to be several thousand feet in thickness, and untold ages elapsed while they were forming. For the purposes of this discussion we need go no farther back in the eons of the past than the time when the Murraysville gas-sand (taking a definite stratum to avoid confusion) was completed by those changes of conditions—whatever they were—which terminated the sand deposits at that spot and commenced to lay down the overlying shales. At that date the two most important requisites for a future gas-field had been provided. The gas-making material had been deposited; the receiving tank, so to speak,

put in place, and the impervious cover was being put on. But the sedimentary deposits were not yet completed. Other carbonaceous shales, other sandrocks, alternating with beds of coal, slates, fire-clays, and limestones were yet to be superimposed to a height of 3,000 feet or more. These all were deposited in the course of time in regularly stratified layers, showing that no deep-seated, unequal or local disturbance had occurred up to the date of their completion. Subsequently some great change took place. The whole region was lifted above ocean level; the Allegheny mountains rose in crested ridges and the Murraysville anticlinal with other comparatively minor flexures was formed.

Now what effect could these anticlinal movements have had upon the gas-producing capabilities of the rocks at Murraysville, where, as we have seen, the gas materials and the reservoirs had been provided ages before? Had the hydrocarbons stored in the shales lain dormant all these ages awaiting some awakening energy to set them free which could only be furnished by the crush and pressure accompanying anticlinal movements? This can hardly be admitted, for oil and gas are plentifully found in regions where the rocks have not been so affected. Did the anticlinal movement open up crevices below the gas-sand leading down to some deep-seated store-house of gas beneath the sedimentary rocks? This question is open to the same objection as the former one; and, furthermore, is it not reasonable to suppose that the side thrust and pressure which caused these anticlinals to rise would have a tendency to consolidate the basal shales confined under a heavy mass of incumbent strata, and to fracture and loosen the rocks near the surface if anywhere? Is it probable that gas after forcing its way up through thousands of feet of clay-shales and slates, such as have been penetrated by wells to the depth of at least 1,800 feet without encountering any noticeable leads, would stop in the gas-sand, only checked by a covering of a few feet of clay-shale overlaid mostly by sandstone to the surface?

If then, anticlinals had no part in depositing the gas-making materials and sand-bed reservoirs, were not the

special agents that caused the generation of gas to commence, and did not open crevices to deep-seated sources of unlimited supplies, what other favorable conditions could they have been instrumental in originating to make them more prolific in gas now than any other locality? I can imagine but one, which is this: When the anticlinal up-lift tilted and warped the previously horizontal strata, destroying the equilibrium of the fluids in them, a new adjustment of their positions in the sand-beds followed. This readjustment, in cases where all the conditions were favorable, probably resulted in storing larger quantities of gas in the anticlinals than elsewhere; but we have no assurance that all the arches were thus fortunately circumstanced, or that the conditions making one part of an arch productive would be equally efficient in another part.

The drill has demonstrated that the permeable sand rocks lie in beds so enclosed in impervious shales that each bed practically forms a reservoir by itself. (See I^3, Chapter 25.) In certain horizons these sand beds are numerous and persistent, as for instance, in the Venango-Butler group. But each individual bed has its *locus* and its characteristic fluids. In the same well one may produce water, another oil, another gas, another a mixture of all three and only a few feet of shale intervene between the different layers of sandstone. All these rocks were equally affected by the general uplift and now lie dipping to the southwest at an average rate of from 18 to 22 feet per mile. (See I^3, Plate 8.)

If the sand rocks were continuous, instead of being in chains of beds or pools, and sufficiently porous to allow fluids to circulate through long distances, say, for instance, from the southerly part of the Butler oil belt at Herman station to Murraysville—then according to the principles upon which the anticlinal theory is founded, the Murraysville rock should now be deluged by water while the Herman Station rock should be stored with gas; for the monoclinal slope of 22 '± to the mile would submerge the anticlinal at Murraysville where the gas sand on the crown of the arch is more than 200 feet lower than it is at Herman Station.

In applying the anticlinal theory to locating gas-wells, this great monoclinal slope has, in most cases, been lost sight of by those who do not understand the geological structure of the country. Knowing the tendency of gas to seek the higher levels, and only stopping to learn that an anticlinal is an arch in the rocks, they procure a geological report, trace out the anticlinal referred to, secure leases upon it, as they suppose, and drill wells. If no gas is obtained, the Survey is charged with not having located the anticlinals correctly. They overlook the fact that the crests of anticlinals slope with the progressive dips of all the rocks towards the south-west, and that this has an important bearing upon the question of anticlinal reservoirs. For example, the Brady's Bend arch is 450′± lower at the Ohio river than it is at Lardintown, Butler county; the Murraysville axis is 250′± lower where it crosses the Pennsylvania railroad than at Murraysville. Now, if the whole county between Lardintown and the Ohio is underlaid by a permeable sandstone containing water and gas, and which produces gas at Lardintown, on the crown of the arch, and water on its flanks (in the synclinals,) say, 225 feet below its crest, then, if the fluids are free to seek natural levels, water would cross the anticlinal's crest half way between Lardintown and the Ohio (for there the crest has fallen 225 feet, which puts it on a level with the watered synclinal at Lardintown,) and going south-westerly from that point the anticlinal must be as thoroughly water-logged as the synclinals. Hence, this universally-prevailing monoclinal dip is quite as important a factor in locating gas-wells as the anticlinals are; for, while the former affects the whole country, the latter only favorably affect local areas.

This persistent south-westerly dip has been referred to time and again in our geological reports. From the oil-fields of New York to the gas-fields of Pittsburgh it may be noticed that the south-westerly ends of productive pools frequently contain more water than the higher slopes. The Brady's Bend axis has been found full of water up to a certain point going north-east; so has the Murraysville; so has the Bull creek or Tarentum. In fact, if the anticlinal

theory is worth anything, this phase of it requires to be specially studied.

As before stated, the productive sandrocks of the oil-regions are generally deposited in elongated beds, stretching out in a north-east and south-west direction. One of these, containing water and gas, might lie between two anticlinals scarcely affected by either; in which case, according to the anticlinal theory, the elevated north-eastern end should be good gas-territory, although it might lie exactly in a syncline. Another bed might trend down from the unwarped regions at the north and have its southerly end uplifted by an anticlinal. Say it is ten miles long—nine miles on the monoclinal slope carries it down about 200 feet, and if it rises 100 feet in the next mile to the crown of the anticlinal, it is there level with a point in the same stratum four and a half miles from its northerly end; and should the sand bed contain a little more water than gas, or its southerly end have less storage capacity than its northerly end, the sand on the anticlinal would be as completely water-logged as in the synclinal north of it. Carrying the illustration still farther, if another sandrock at a higher or lower geological level commences under this anticlinal and extends southwardly, it should be gas-bearing not only on the anticlinal, but also in the syncline towards the south, unless it has but little length or is uplifted by another anticlinal a short distance south.

The effects produced by an anticlinal are further modified, no doubt, by the partial or complete porosity of the sand-beds, the relative proportions and qualities of the fluids contained in them, and the different degrees of pressure under which they are confined.

These may be called fanciful suppositions, but they are neither impossible nor improbable, and knowing that such heterogeneous physical conditions may exist, we should be warned that no theory based on *one idea*, however plausible it may appear, is worthy of acceptance. Yet, locators with such theories are most in popular favor, even with many who very well know (if they would but pause to consider) that no man in any age, whatever his pretensions

may have been, ever discovered an infallible rule for unerringly locating ore beds or oil and gas wells. And we may confidently add that the diversified conditions under which all minerals exist make it absolutely certain that no such rule ever will be discovered. The oil regions are strewn with financial wrecks caused by an overweening confidence in one-idea theories delusively formulated upon accidental successes and often having no foundation whatever in fact.

8. *The inexhaustibility of natural gas wells* is another popular fallacy which has gained some standing since drilling for gas commenced near Pittsburgh. It would seem that the patent results of oil and gas developments in Pennsylvania during the last twenty-five years ought to satisfy even the most superficial investigator that such a theory is absolutely untenable. But these theorists affirm that the Pittsburgh gas pools are unlike those in the old oil-regions, in that they receive their supplies from a deeper and never-failing source. How this belief can be entertained—except through ignorance of the true conditions existing—it is hard to comprehend; for it is clearly demonstrated that the gas-producing rocks of both sections belong to one and the same age, are identical in structure and characteristics, and have similar geological associates above and below them.

A permanent gas-field implies a number of necessary conditions, and suggest many curious questions—among which are the following:

Inexhaustible wells must draw from inexhaustible sources. Gas in Pennsylvania is only found in sand-beds of medium thickness and restricted geographical limits. Such beds, in themselves, cannot be inexhaustible. Their productive duration depends entirely upon the drafts made upon them—a simple problem—if one well can exhaust one of the beds in 100 years how long will it take 100 wells to do it? To make such pools permanent they must be constantly replenished from an unlimited source. This source, it is claimed, is some deep-seated laboratory

of nature capable of responding to all demands that can be made upon it.

The present draft upon the Murraysville pool, (and it is being increased weekly by new wells—if, as it is claimed, the pressure is not diminishing) would probably require a feed pipe at least two feet in diameter to maintain it. Now if the pool is inexhaustible, it must be connected with the unfailing supplies by conduits of larger capacity than this, for the number of wells drawing upon it will soon be more than doubled.

But supposing the conduits to be equal in carrying capacity to a two-foot pipe only, how long would it probably take the unlimited gas-making power to fill the Murraysville sand-bed? Ought not ten, fifteen, or twenty years to suffice? Could it *possibly* require one hundred years? And if it did, what an insignificant period of time is that in the annals of the past! Can it be possible that natural gas commenced to generate in unlimited quantities only in *very recent* times? Otherwise, what has become of the gas produced during former ages? When the sand reservoirs were filled, did the gas-making stop? If so, what was the maximum pressure the generating forces were capable of, and why should not all gas pools now be found under a like pressure? What prevented some of these pools from becoming overcharged and exploding? A pool with only 600 feet of cover, (and gas is often found at less depth) could not be charged under a pressure of 1,000 lbs. to the square inch, as Murraysville is supposed to have been. Before attaining that point the surface rocks would be lifted and fractured, and the fractures once opened would become permanent gas vents—if gas wells are to be permanent. Is it not remarkable that no such shattered gas pools, no such large gas vents, are to be found? Perennial gas springs abound in some sections of the country, but if the permanent flow from them is to be taken as the measure of the capacity of the gas generating forces, it is evident that it is altogether too insignificant to meet the demands of inexhaustible theorists.

The gas deposits around Pittsburgh are evidently large

and well stored, and capable, no doubt, of supplying a reasonable number of wells many years. But if too copiously drawn upon—as they are likely to be under the present contagious excitement—not alone for the purpose of supplying legitimate demands, but also through excessive drilling in all directions by parties who have no gas mains, but lease and drill as a matter of speculation, wasting the gas if successful, until a satisfactory sale can be forced—they must soon become exhausted to such a degree that it will be found necessary to extend the gas mains to new pools (if they can be found) or to supply them with manufactured gas.

Sooner or later these results are inevitable, for it may be affirmed with great assurance that there are no tenable reasons for believing that the gas pools of Pittsburgh can endure a constant and excessive drain without sharing the fate that has overtaken all the old oil and gas pools along the oil belt.

CHAPTER V.

What remains unchanged in our past knowledge of the Geology of Petroleum.

Introduction.

[The chief end of applied science is to teach practical principles by a recital of actual facts.

All the wisdom of the world is based upon the history of men's doings. True philosophy is history teaching by examples. Real science rejects every theory that has not stood the test of experience, and accepts every theory which proves itself by successful predictions.

"The test of science is the power of prediction," but the basis of science is the history of facts. Men are so pleasurably stimulated by new ideas, whether wise or foolish, proved or unproved, that they allow to drop out of their memories the positive information which past facts have afforded; hence, the chief business of science is to collect, arrange, and impress upon the public mind that mass of already existing information which is the only check upon a popular lust for novelties, and the only sure guide to sound practical knowledge.

I take this opportunity for vindicating the character of the work of the Survey.

It has been said in the Oil and Gas region that the Geological Survey of the State has been merely a recorder of already well known facts, and of new discoveries, not made by its geologists, nor by any geologists, but by unprofessional prospectors and well drillers; that, granting the utility of statistical and historical information, yet the Survey has been of little practical use to citizens, because, instead of leading them to discoveries, it merely followed them with the purpose of recording their discoveries; that it kept behind the times, and knew less than the people of the State whom it pretended to instruct.

This charge has been advanced against every geological survey by persons of limited experience and education, but especially by such as have a strong prejudice in favor of some train of ideas of their own which they feel proud of and desire to introduce into the public mind. Their own minds not being disciplined to the patient and accurate investigation of the facts, they expend their enthusiasm for the wonders of nature in manufacturing explanations for them out of a too scanty stock of materials.

The charge is improbable on its face. The local prospector is intelligent and knows a great many facts, and is well acquainted with all the features of the surface; but the geologist who knows all the surface features and in addition to that is well acquainted with the underground can certainly form better judgments. The well driller is a man of intelligence and large experience of a certain class of facts; but his attention is almost exclusively devoted to these, and his chief desire is to get down as speedily as possible and at the smallest cost to some rock on which he has fixed his mind; so that in all the wells he has drilled he has paid little attention to the special order and character of the measures overlying it. It is evident that he cannot be so good a judge as a geologist who has laboriously compared a thousand well records and a thousand outcrops to learn the whole truth. As to men in business, how is it possible for them, with their attention distracted by innumerable side objects of interest, pecuniary and executive, to know as much about purely geologicial subjects, like oil and gas, as geologists whose entire time is given to the investigation of such subjects; to placing all obtainable facts in every possible light for reflecting the truth; who are uninfluenced by personal interests and undistracted by business engagements? In fine, how is it possible for the most thoughtful and capable man who only knows with certainty the facts of his own neighborhood to form a better judgment, or have truer information, than the geologist who has already prepared himself for the thorough investigation of that neighborhood by a long and thorough study of many other similar regions?

To say the least, such a conclusion is improbable. The thing speaks for itself. It will certainly be conceded that professional geologists are as intelligent as other men; and it must be conceded that their opportunities for wide and accurate information respecting geological facts are much greater than those of other men, equally intelligent. It is not immodest for geologists to say this publicly when their competence as public experts is called in question.

Western Pennsylvania now stands in a very different attitude to the State Geological Survey from what it did ten years ago. The work of the Survey has laid a wide and deep basis of knowledge, which has been admirably built upon by the citizens of the region, many of whom have become perfectly well versed in the true principles and methods of geological research, and have been applying these methods and principles with eminent skill and success to the solution of local problems—skill as well disciplined and success as great as any assistant on the State Survey could expect to command for himself. Nothing could be better done in any geological field than what is now being done in the Pittsburgh gas and oil region, in watching wells as they go down, getting and comparing well records, identifying special rocks from well to well over considerable areas, using a fixed basis of measurement like the Pittsburgh coal bed for determining the depth of oil and gas-bearing sands, referring well-mouths to tide-water by railroad levels, calculating dips and locating anticlinals and synclinals. Principles are sound and methods are scientific, but it should not be forgotten that they are due to the instruction and practice of the State Survey. But this is precisely what the public at large does not appreciate, and which it is part of my official duty to accentuate, ungracious as it may perhaps appear to some. Those who have reaped most advantage from the State Survey will not think it so.

I suspect that people at large do not properly appreciate the distinction between *professional* and *professorial* geologists. They confound "field-workers" with "closet-geologists;" "practical geologists" with "geological school-

teachers." But the two classes differ as widely as parish clergy differ from monastic orders; for. while the one class consort together and cultivate their minds on the science which they find in books, the other class live separately from one another, at large among their fellow-citizens, consulting with every class of the community, receiving and giving mutual information, investigating facts at first hand, looking at things with their own eyes, and yet with whatever advantages book-learning can afford for widening the vision and steadying the judgment. So, in the course of years, a thorough-bred field-working geologist gets to be as wise in the things of the mineral kingdom as a Wesleyan minister, who has been transferred every two years to a new parish, in the knowledge of human nature.

Knowledge is often obliged to confess its ignorance; and the best knowledge does this most readily, when the occasion arises. Ignorance does not willingly confess ignorance, usually, because it does not know enough to recognize its ignorance. Thus it happens that ignorance often looks wiser than knowledge; and the geologist who answers a point blank question with "I do not know," is accounted ignorant of his business; yet, he alone knows where the limits of knowledge lie, and he alone can gauge the ignorance which pretends to be knowledge. To say "I do not know" requires courage, but this courage, like the soldier's, is acquired in the field.

Every science, like every art, has a lawful warrant to protect itself against the aspersion of uselessness, and to justify its proper calling. It is idle to deny that it is in its own special field the illuminator of the material world. It is divinely appointed to

> **"Tell men what they knew before;**
> **Paint the prospect from their door;"**

that is, to give men a new and more truthful vision and the real meaning of things with which they have been long familiar without properly comprehending them. The geologist's question, "Have you not seen so and so?" is usually answered by "Yes, but I did not suppose it to be of any

importance." When men buy spectacles from science, they find out that they have been more or less nearsighted. Familiarity breeds a contempt for many facts. But the geologist is trained by his whole life not to neglect or think the smallest item of fact unimportant in the pursuit of his investigations. On the other hand, the prospector, the well sinker, and the business man are seldom thus trained. They get the habit of thinking many things of little or no importance. In fact, it is not to be expected of those whose chief business is not investigation, but action, that they should be able to distinguish what fact is important and what is unimportant in an investigation. Lawyers tell us from their experience of cases that the issue of a case usually depends upon some item of its history which *nobody but a lawyer* would think it worth while to mention either in or out of court.

There are thousands of such examples to be found in the past history of geology. Here is one. Indians, French soldiers, early white settlers, raftsmen, bargemen, steamboat hands, in fact every traveler up and down the Allegheny river valley, had noticed that the rocks along the cliffs of the river generally sloped down stream; thought it quite natural and proper that they should do so, but thought no more about it. It was a fact without any significance to them. Yet, in 1837 and 1838, the geologists of the First Survey saw at once in this slope the key to the whole geology of the underground of Western Pennsylvania. Years went by, and no one read the reports of those geologists. People continued to travel up and down the Allegheny river as before, just as indifferent to the slope of the rocks, and just as ignorant of the underground geology which it expressed as ever. For, when in the spring of 1865 I used this slope of the rocks to calculate the place of the three Venango oil sands at Brady's Bend, fixing their depths at 700, 900, and 1,100 feet, and when on the basis of that calculation Brady's Bend well, No. 1, was drilled and struck oil and gas, at 940 feet, and at 1,089 feet, producing at first fifty barrels a day, everybody was as much amazed as if there had never been published a geological description of

Western Pennsylvania. They lauded the accuracy of the prediction as a marvel of geological genius, although it was nothing but the ordinary work of an assistant geologist of the First Survey applying to a special local investigation principles which had been fixed by that Survey, merely taking care to leave nothing unobserved, and thinking out this special problem without any individual bias of theory to distract his attention from the facts of the case.

No one then heard it said that geologists were always behind the time, and merely recorded the discoveries of others. In the light of such a case such a remark would have been scouted as absurd; and it is just as absurd in 1885 as in 1865.

I am safe in saying that the work of the Second Geological Survey, begun in 1874, has always been in advance of the knowledge possessed by the citizens of Western Pennsylvania; and that it has been a fountain of practical instruction in the geology of oil and gas; and that entirely apart from its publications in book form. It has not only described what people had not noticed, and explained what people did not understand, but it has predicted what would happen in the history of the oil production, and its predictions have come true; which proves the accuracy of its work and the soundness of its reasoning.

As it is of some importance to substantiate this assertion, I take the opportunity afforded by the publication of Mr. Carll's preliminary report in the Annual of 1885, to give the evidence, in the shape of a remarkable article published by Mr. Carll, at my request, in the leading newspaper of the region, the *Oil City Derrick*, its issues of July 24 and 25, 1876.

The article is, and was intended to be, as accurately defined and complete as possible a summary of the knowledge obtained by the Geological Survey up to that date, and was published in advance of the regular Reports of Progess, to supply an urgent demand from all classes of people interested in petroleum, for the best practical information respecting its geological relationships. What the effect was in giving new and true ideas of Oil Geology, those who took

advantage of it can best tell. After ten years of universal exploration it still stands as the truest statement that can be made. No essentially new truth in Oil Geology has been discovered to add to it; and it therefore merits an official publication now, as much as it did then. But what is more to the present purpose, it contains predictions which have come true; such predictions as the most expert prospectors, drillers and oil men of the region could not make; predictions which depended upon the closest and widest study of all parts of the Oil Regions, such as the geologists of a State Survey alone have the opportunity of pursuing.

With this introduction, I place it on public record for the benefit of all concerned, and as one instance of many in testimony to the character of the past work of the Survey in Western Pennsylvania.—J. P. L.]

[Extract *Oil City Derrick*, July 24 and 25, 1876.]

The Second Geological Survey of Pennsylvania has now been in progress nearly two years. In the Venango district. (the district of the oil regions) some advance has already been made towards clearing away the clouds of false impressions and confused theories which have so long obscured our knowledge of the structural geology of the oil measures; but much, very much, remains to be accomplished before the final results, now dimly foreshadowed, can be so clearly demonstrated as to become of practical use to the oil-producer or be accepted as facts by the scientific world.

With a view, therefore, of attracting the attention of the oil-producer to our work, and of soliciting his hearty co-operation in its advancement, (for, without his aid, but little progress can be made,) the director of the Survey, Prof. Lesley, has advised the preparation of a short article for general circulation, giving the broad outlines of the situation in this district from the present outlook. It is hoped thereby that many will be reached who might never take

the trouble to read our annual reports, and that an interest may be awakened which will result in much valuable information to the Survey and to the world.

Within the prescribed limits of this paper it cannot be expected that the details and proofs of every position assumed will be given. Neither will it be presumed that at this stage of the work every idea advanced is absolutely correct. Material modifications, no doubt, will be found necessary as the Survey is carried forward and new facts are brought to light. I shall simply aim to present *a general view of the subject as it now appears*, with no intention of clinging to any theory of my own, and with only a sincere desire of enlisting the thoughtful attention of those engaged in the oil business, in order that, by their aid, correct results may be arrived at and the common welfare of all interested advanced.

General propositions.

Some of the conclusions already foreshadowed by the accumulating data of the Survey may be broadly stated—not dogmatically—but briefly, as follows :

First.—A paying oil-well in this section of the State is only obtained where a good sand-rock is found.*

Second.—These oil-producing sands form a group of themselves, with well-defined beds of slates and shales, at least one hundred feet in thickness, both above and below it ; and, whether composed of three members, as on Oil creek, where they were named First, Second, and Third Sands, or split into five or six members, as they usually are to the south-east and east of the central line of the group, they all lie, as a general rule, within a vertical range of three hundred and fifty feet.

Third.—This group or belt of oil sands has been traced from Tidioute, in Warren county, to St. Joe, in Butler county—say, sixty miles. About 15,000 oil-wells have been drilled upon it, and the indications are that its north-west and south-east limits have been pretty well defined. What

*It will be borne in mind that nothing in the first part of this paper has any reference to the oil measures of Bradford and Warren. They are spoken of separately in the concluding pages.

becomes of it to the east or north-east of Tidioute, and how far it may continue south of St. Joe, remains to be ascertained, nothing but "dry-holes" or small wells having thus far rewarded those who have attempted to trace the prolongation of the belt at either end.

The whole group, as thus defined, will not average over ten miles in width, and probably not over one tenth of the area of these 600 square miles of oil sands is underlaid by that peculiar, pebbly, porous sandstone, which alone produces the oil in paying quantities.

Fourth.—On the central, or "green oil" line of development, the well records show great uniformity in the arrangement of the sand-rocks. They are sharply defined, massive, and lie at regular intervals. Going south-east from this line they gradually split into several members, fine down in their composition, and shade away into shales, while the intervening members become more frequently and heavily interstratified with red rocks. Going to the north-west, the Third Sand terminates rather abruptly, the Second Sand overlaps it and continues a mile or two farther; the First Sand overlaps the Second and extends, in some places, a long distance beyond.

The majority of the wells producing from the First and Second Sands are located along these overlapping edges of the sand-rocks.

Fifth.—The *lowest member* of this sand-rock group—the Third Sand of Oil creek or green oil sand—has been erroneously called in different localities the Fourth, Fifth, and even Sixth Sand, conveying the impression that there are other oil sands below the Oil Creek Third, which, as far as known, is not the fact. I have found no authentic evidence of any oil sand belonging to this group below the horizon of the base of the Oil Creek Third.

The green oil sand is much narrower in its transverse producing area than the stray or black oil sand, which lies about twenty-five feet above it, (but which may be considered as the upper member of the Third,) the Second covers a wider area than the stray Third, and the First Sand is wider than the Second.

Sixth.—Wherever the Third or *lowest sand* is adapted to the production of oil, the main deposit is found in it, and not in the sands above. The First and Second Sands, although often of good quality, do not produce oil along the center of the belt. In some wells, it is true, oil has been obtained from all three of the sands. These wells are not on the axis, but near the edge of the Third Sand, and but a short remove further from the center no Third Sand can be found.

Seventh.—Each one of these three sand-rocks, where they lie in clearly defined beds, furnishes an oil peculiar to itself. The First Sand, a heavy lubricating oil from 30° to 35° gravity, the Second Sand, an oil of about 40° gravity, and the Third the usual light oil of from 45° to 50° gravity. But, while each sand has its own characteristic production, the oil varies somewhat in color and gravity in different localities in the same horizon. Thus, the Third Sand produces a green oil from its lower member and a black oil from its stray or upper member, where the rocks lie in their normal positions, as on Oil creek; but, where the stratification varies—thus changing the relations of the several members to each other both as to thickness and composition—the oil is changed in color accordingly. At Pleasantville, where the lower member is thicker than the upper, but fine and muddy—and the upper or stray is coarse and gravelly and produces the oil—its color is nearly black. At Pithole, Cash-Up and Fagundus, where the lower member has fined down to a thin band of argillaceous flags, and the upper member thickened into a pebbly sandstone, the oil is of a lighter color. In some parts of Clarion and Butler, where the horizon of the Third Sand is represented by three or four beds of pebbly sands—sometimes producing oil from one stratum and sometimes from another—the colors shade intermediately between the green and black oils of the upper country. These shades are so gradual and slight that they have not been generally noted, but a critical examination of a number of wells will convince any one of the fact.

The group of oil sands.

The first general proposition above will not be disputed, I think, by any experienced oil producer.

The second, no doubt, is a "new idea" and demands explanation. I regard it as one of the most important facts thus far brought to light by the Survey. It was first mentioned in my report of 1874—speaking then only of the rocks of Venango county, (at that time no others had been examined) and with no idea that the group would run with such remarkable uniformity through the whole Oil Region, as we can now plainly see that it does.

To clearly demonstrate this, however, would require a number of wood-cuts and a careful comparison of many oil well records on the central line of development, with frequent transverse sections along the belt. This belongs to our regular reports, and cannot be attempted here. More data are needed in the shape of good well records, before it can be systematically and satisfactorily laid before the public. As these records can only be obtained through the kindness of those who are engaged in sinking oil wells, we earnestly solicit their aid in this important part of our work.

Confused nomenclature.

Very great confusion has arisen from the want of a uniform system for numbering or naming the oil sands. Every district has its own nomenclature, and owing to the large number of local names in use, and the variable stratification of the sand rocks—when viewed indiscriminately, without regard to their true lines of deposition and agreement—the most experienced driller is at a loss when attempting to assign the rocks of one place their correct relative positions in another.

The Third-sand at Triumph, near Tidioute, the thickest yet found in the country, is called in Pleasantville, the Fourth and Fifth sand; at "Red-hot," the Fourth, Fifth and Sixth; on Oil Creek, stray and Third; at Foster's, gray-rock and Third; at Scrubgrass, granite-rock and Third; in the Clarion county district, bowlder, stray, Third and

Fourth, and in Butler, blue-Monday, bowlder, stray Third, Third, stray Fourth and Fourth. On studying the group of sand-rocks, as a whole, it plainly appears that these names are all applied to different parts of what is really but one sand—the Oil Creek Third. At Triumph it lies in one massive stratum, 125 feet thick; in the other places it is laid down in a series of bands with partings of slate, shale and red-rocks between.

The attempt to name these smaller beds and to trace them from one district to another, without an appreciation of their variableness and liability to run together or separate—to thicken into heavier sands or fine down into shales, according to the direction they were being traced—has proved very disastrous to a clear understanding of the geology of the oil measures. Locally, perhaps, some of these names may be of service, if recognized merely as subdivisions of the Third sand, but unfortunately they cannot be confined within their proper limits. Oil well drillers are a migratory class. When one field is explored they move on to another, carrying with them their thorough knowledge of the district just left and looking at the new field through their experiences in the old. Thus different names travel from place to place, and are often applied, (where some new bed of sand intervenes or some old one is wanting) to quite different horizons from those for which they were originally invented. Sometimes they are placed too high, sometimes too low; and not unfrequently two bands are transposed—blue-Monday, for instance, coming in in one place above the Bowlder, and in another place below it—in one well representing a rock two feet thick, and in another fifty feet.

I do not mention these things disparagingly to the driller, (for it is not within the range of human possibilities to trace these divisions separately over the whole country) but for the purpose of showing the extreme variableness of the oil sands and the liability to mistakes when attempting to transfer the local names of one place to another. From the very nature of the case, we could not expect these sandrocks—laid down as they were by water cur-

rents, and subject to all the vicissitudes of tides and storms and winds—and no doubt, too, to changing levels of land and water, to be spread uniformly and uninterruptedly over so large an area as they are known to occupy.

The difficulty here complained of in relation to the Third-sand will apply with equal force to the Second and First-sands also. Their true classification has been obscured in the same manner. Other rocks, duplicating the originals, have been found and named—little attention has been paid to the measurement of the wells at this horizon, and all is uncertainty and confusion. This is especially the case in the Clarion and Butler districts. The First-sand of Clarion (which fortunately coincides with the First-sand of Oil creek,) is almost universally called the *Second*-sand in Butler. The so-called First-sand of Butler is the equivalent of the Third Mountain sand of the upper district, which is probably the Berea grit of Ohio. It has no connection whatever with the oil sands of this district—being generally separated from the group by several hundred feet of slates or shales—and no claims to a name among them, although it is the oil-producing rock in Ohio, and in lower Butler often furnishes a large flow of gas.

In the valley of Oil creek, three sand rocks were discovered by the first oil well drillers and very properly named the First, Second and Third-sands. These names have gone abroad and been accepted by the world; and there is no reason why they should now be changed. They apply appropriately to the three distinctive rocks of our great sand belt, embracing, as far as known at present, all the oil producing strata of this particular district. The group is separated from the next massive sandstone above, (the Third Mountain sand or Berea grit) by from one to two hundred feet of slates, shales and red rocks—these varying according to location, and no oil producing sand has been found in any of our deep wells—a number of which have been drilled 1,000 feet beneath it. Why should we attempt then to add to it either from above or below, and thus becloud our own ideas and mislead others who infer from our method of numbering that we are discovering new oil rocks in addition to those first named?

The way to avoid this labyrinth of confusion in the future is to *study the oil-sands as a group*, and while noting closely the local divisions of its three great members, never to lose sight of the fact that whatever may be the number of these minor divisions, they have always thus far been found to lie in the horizon included between the plane of the top of the First-sand of Oil creek and the plane of the bottom of the Third-sand, the two planes being separated vertically by a distance of about three hundred and fifty feet.

Accurate measurements should always be made when the First-oil-sand is struck, and the driller should be very careful in new territory to see that the proper rock is thus designated. It is the key to the whole record. The true First-sand is easily recognized by being overlaid, as before stated, by from one to two hundred feet of slates and shales, sometimes in part red. This shaly band is generally the best drilling in the well, and it is a marked and persistent feature in all parts of the district. From this point (the top of the First-sand) to the bottom of the well, every change in the rocks should be noted. But it would be better still to keep a close record of the whole well.

Had the records been thus kept when the first wells were put down at Petrolia, the so-called Second-sand would have received its proper designation—the *First*, as it really is—and the depth drilled below it would have shown at once that the so-called Third-sand was not the lowest member of the group, and that another sand might reasonably be expected to lie beneath. The so-called Third is only about 250 feet, and the so-called Fourth less than 350 feet below the true First-sand. Of course, it could not have been known that the lower sand would produce oil, without drilling down to it, but with the method of classifying the oil rocks here proposed, and the habit of viewing them as one group, there would have been no surprise at finding oil in the lower member and no necessity of naming a Fourth Sand.

The Oil-sand belt.

My third conclusion is broad and general, as it must

necessarily be at this stage of our work. But broad as it is, it shows the oil-bearing rocks' to be of very limited extent, even when given the utmost latitude which our present knowledge of them would warrant.

I ask those who have followed the development from Tidioute to Butler, to candidly review their experience, and see whether they would give these rocks a wider range than I have done. Would any of them go five miles to the north-west or west of the central line, or line of the best production, with the expectation of finding oil in the Third-sand? Going in that direction, do not the Second-sand wells (wherever the Second-sand contains oil) come in quickly after leaving the green oil line—then the First-sand wells, and then the hundreds of "dry holes," scattered all through this country to Lake Erie and Ohio? Have there not been enough wells drilled in this section, as far down as Scrubgrass at least, to prove that this particular sand rock group does not extend far to the northwest of the central developments? And may it not be expected that the same conditions will continue still farther south, although this end of the belt has not been so thoroughly tested? Going to the south-east from the center, would not five miles be a liberal allowance for the average width of the producing territory in that direction, and have there not been hundreds of "dry holes" put down here also, where only thin beds of flaggy sandstones represent the oil rocks and heavy masses of red shale appear?

What is the inference then? Plainly, that the area of our oil-sand group, as now known, and, we may say, *proved*, is confined within very narrow limits transversely.

It may be asked: "Are there not other parallel ranges of oil-sands belonging to the same measures?"

The rocks of the whole country rise towards the lake, and if the oil group continued in that direction, or another parallel belt came in, they would outcrop along the basset edges of the lake shore terrace. But nothing of the kind can there be found; neither have the numerous oil wells drilled in all this northwestern area given any indications of their presence. To the south-east, the farther develop-

ments have been carried, the finer and more shaly the measures became—indicating, apparently, a deposit in deeper or more quiet water at a considerable distance from those current or shore influences which seem to have been the controlling agents in the formation of this sand deposit. It can hardly be supposed, therefore, that another belt lies in this direction, unless at a considerable distance, and I see nothing *at present* in any of the data collected to warrant the expectation of discovering large and continuous deposits of oil at this horizon, either to the right or left of the belt as here defined.

Within the limits of the sand-belt itself, no doubt, many other pockets of gravel and pools of oil of limited extent will be found. The strict adherence to the popular "line theory" confined the first drillings to a very narrow strip of land running longitudinally along the sand group and probably near its axis. But even now good wells are rewarding the seeker on either side of the original line in what was considered "dry territory" during the first excitement. When these marginal pools are more fully developed, the wells will be scattered over a wider area, and the similarity between the Butler, Clarion, and Venango districts made more apparent.

If we knew precisely by what agencies these sand rocks were deposited—whence the materials composing them were derived—the direction of the transporting currents, and how these currents were locally or periodically affected by tides and storms, and oscillations of land and sea—resulting in altered topography of shore-lines or sea-bottom, and a consequent change of currents and sand-deposits—we might be able to trace and outline the oil-group with some confidence and accuracy. But we do not yet know how they were laid down—whether by a deep sea current like the gulf stream or as sand-beaches along a low coast line of recently emerged Chemung.

The sandy epoch.

Whatever may have been the method of their deposition, however, this fact appears quite evident—they mark *the*

commencement of a sandy epoch in the history of the geological formations of this particular part of the State. The measures below them have been pierced by the drill in a number of places to the depth of a thousand feet or more, and, in one instance, to the depth of three thousand feet without finding any coarse, massive sands, like the Oil-group. But from the base of the Third-sand, (which is in some places a true conglomerate of large quartz pebbles and sand,) all up to and through the coal measures, the whole sedimentary mass is thickly interstratified with parallel layers of conglomeratic sandstone. The remarkable similarity in the composition and stratification of the oil-group to the Mountain sands and Coal measure sands, and its striking dissimilarity to the measures below suggest a subject of very interesting inquiry as to the relations of these several groups to each other.

Variable deposits—Belt lines and surface indications.

I have spoken of the oil-rocks as one continuous group from Tidioute to St. Joe. Some may not be willing to concede this, on account of the apparent "break" in the belt between Scrubgrass and Emlenton. But it should be remembered that I am speaking of them in the broadest sense—as a deposit of a certain period, over a large area—without reference to local peculiarities of deposition or composition. A band of "shells," which the driller would hardly notice, may as truly represent the horizon of a sand-rock as the best deposit of pebbly oil-sand does. Given sand, pebbles, and mud to be worked and transported by water, and nothing should be expected but a variable deposit, dependent entirely upon the local conditions controling the direction and force of the currents.

If we view these deposits as the products of deep sea currents, we might anticipate finding the sediments more evenly spread and more continuously laid down than they would have been along a coast line. Disturbing causes would not be felt so appreciably in a deep sea as along a shore; but in either case, comparatively slight perturbations might produce sufficient change in the direction and power of

the currents to materially alter and modify the first arrangement of any deposits. The Third Sand, for instance, might have been laid down originally in an almost unbroken band from Tidioute to St. Joe, through a long period of comparative rest; but only a slight subsequent oscillation of levels would be required to alter the transporting currents and completely re-arrange the deposits along those portions of the line most affected by these changes. At one point the sand might be swept away and carried to a new position, at another additional sands be added to those already laid down.

The mere mention of these possible changes—to which all the sedimentary rocks were liable—should suggest to those who depend so much on compass lines in locating their oil wells, the uncertainty of this reliance, (when not coupled with a close study of the oil rocks themselves) especially when lines are run far in advance of actual developments. It also shows the fallacy of attempting to trace the oil belt by the exposed sand-rocks or conglomerates on the surface. If there was originally no regularity to the deposits individually, and no fixed law requiring them to be laid down in fixed uniformity either as to the thickness or outlines of the beds, or the position of the gravel streaks in those beds—if there was no compass and plummet used in piling up these sand-beds, one over the other, how can it be expected by the compass and plummet to trace them from the surface rocks downward to the base?

To make this more plain let us go back in imagination to that period in the world's history when the oil sands were being laid down. Old ocean, "the great continent builder," is preparing the ample storehouses of gravel sands, from which we now draw our petroleum supplies. Age after age the slow processes go on. Heat and cold, waves, winds, and currents are employed—breaking up and transporting the materials—sifting, assorting, depositing—here a bed of gravel, there a bank of sand, or a stratum of mud—layer on layer—not all coarse in one place, and all fine in another—not in mathematical lines by plummet and rule—but gravel and sand and shale, in irregularly alternating beds

throughout the whole mass—just as we see the same agencies, carrying on similar processes, and producing like results to-day. At that time none of the hundreds of feet of strata now drilled through before reaching the oil-sands had been deposited. Nothing but the water and air of the ancient world lay above these accumulating sand bars. The materials from which the oil is derived must have been sealed up in the measures below ages before or were then being deposited with the sands themselves, for we can imagine no process by which the oil could be evolved from superior strata and forced *downward* into reservoirs below sea level. The never-ceasing work goes on; slowly the new deposits sink deeper and deeper, or the waters rise higher and higher. Other deposits—the Mountain sands, the Lower productive coal measures, the Barren coal measures, and the Pittsburgh coals, (in all 3,000 feet or more in thickness) are added. We now see our oil-group over three thousand feet below tide with all these superimposed sediments on its back. What ages must have elapsed since the work on the oil-sands ceased! Where now are the landmarks by which to trace the outlines of this long and deeply buried group? Every change of the relative levels of land and sea during this immense period could have only resulted in new shore lines, new currents, new sources of supply and qualities of materials to be acted upon, and consequently, in great variability of the sediments laid down. Would it be reasonable now to infer that a conglomerate seen in the upper stratum denoted that a pebble rock would be found in the oil sands three thousand feet beneath? Could there possibly be anything discovered on the surface to prove what there was below? And if we had ten miles square of any part of these deeply buried oil-sands accurately marked out on the surface above them, could we set a compass on that and stake out the boundaries of the balance?

If, then, no guides to the oil-sands can be seen in the upper rocks while lying in this position how much less should we expect to find them on the surface now that their horizontality has been destroyed! The forces that piled up the

huge folds of the Allegheny mountains, elevated and warped the oil sands with their superincumbent strata also. But as their general parallelism has not been affected, they still occupy their original relative positions, whether arching over the low anticlinals or dipping into the synclinals between. At Tidioute the whole mass must have come up at least 4,000 feet, for the oil group is now found there 1,000 feet above tide. Glaciers, floods, storms, frosts and heat, age after age, have been carrying on their work of erosion, during the uplift or since, cutting off and sweeping away a good portion of the upper rocks, until now in some places the lower member of the oil sands are exposed to the sun.

Along the irregular outcrops of these uplifted strata, one may travel from Tidioute to Butler, as it were, on a line drawn diagonally across the perpendicular face of the original deposits—starting at Tidioute, at the Second-oil-sand, and running up in Butler to the middle of the Lower productive coal measures. This line cuts all the sand deposits of the intervening formations, at least five or six in number. Each one of them is locally conglomeratic. We find them irregularly exposed, according to the elevation of the surface or the amount of erosion they have locally suffered —sometimes showing the pebbly portions, but more frequently the sandy. They are so much alike, lithologically, that one band may be easily mistaken for another, as is no doubt frequently the case when they are traced from hill to hill by the eye. It will be seen, then, that even if the oil-sands of the measures below had been photographed, so to speak, or reproduced in unmistakable outlines on any one of these upper sand-sheets, so that a certain kind of pebble or sand-rock in the upper stratum should point unerringly to the oil deposits below, that it would be as difficult to trace the oil belt by the eye in these upper rocks thus so deceptively exposed, as by the drill in the lower rocks themselves.

Anticlinals.

It follows, also, from the above presentation of the case, that the anticlinals and synclinals now seen on the surface

should not be taken as guides in searching for the oil-sands. These undulations were produced by movements in the earth-crust long after the oil-sands were deposited—as is shown by the fact that the coal measures are equally affected by the same waves—consequently they could have had no agency whatever in controlling and directing the currents which had already laid down the oil-sands thousands of years before. In so far as these anticlinals and synclinals affect the productiveness of the oil-sands, by affording an opportunity for gas to collect at the crowns of the arches and salt water to settle in the depressions between them, just so far ought they to have an influence in the selection of a location for an oil well, and no farther.

Theories for locating oil wells.

Every oil-producer must have a theory on which he acts and a method which he employs in locating his wells, and it is of vital importance to his continued success that his theory should have some foundation in fact. All the methods heretofore employed in the location of oil-wells—clairvoyance, dreams, witch-hazel, Indian charms, magnetism, surface indications, compass lines, &c.—have been measurably successful, so long as they chanced to be confined to the area underlaid by the oil-group; but every one of them has failed the moment it ran outside of these limits, and the fact that they all have at one time or another led their followers outside and into unproductive territory proves that not one of them is based on correct principles and to be implicitly relied upon. The belt line theory has stood the test longer and been more successful than any other, because it has some of the elements of the true theory in it. It is an attempt, by mean of compass lines, to keep on the axis of the sand deposit, as shown by previous development; but, unfortunately for those who rely so much upon it, the oil sand is not laid down in straight and continuous lines through the whole country. It is liable to "breaks" and curves, and they often come in where least expected. To meet these uncertain features belt lines have been required in different places, varying all the way from

east and west to north and south. If there was anything in the belt line theory to indicate in advance of the drill when and where the magnetic bearing should be changed, it would be entitled to great consideration, but there is nothing of the kind; the old line is always adhered to until "dry holes at the front" make a change in its direction imperative.

Viewing the oil-group in its true character—as a mass of variable sands and gravels deposited by one of the most unstable of agents, water—it appears quite plain that no plan of locating oil wells can ever be adopted which will be universally successful. But I claim that the place to look for the guides and indices that will aid us most in an intelligent tracing of the oil-bearing sands is in the rocks themselves, and not in the "powers of the air," nor in the topography of the surface, nor in the structure or position of the superimposed strata. When the oil-group is studied more closely, and less attention paid to these other matters, which can, by no possibility, have any certain connection with it, we shall get clearer views, work more understandingly, and probably avoid a good deal of unprofitable and unnecessary "wild-catting."

Recapitulation.

If the premises assumed at the head of this article are in the main correct—(1,) that a sand-rock must be found to insure a paying oil well; (2,) that all our oil-sands lie in a group, having a uniform thickness throughout the district; (3,) that this group has a general trend in a north-east and south-west direction, being many miles in length, only a few miles in width, and with but a small part of this productive of oil; (4,) that there is considerable uniformity in the stratification of the sand-sheets along the main axis of production, and a marked change as we go to the right or left of that line; (5,) that the Third-sand is locally divided into a number of members, any one of which may produce oil, and that it is narrower transversely than either of the others; (6,) that our main supply of oil is drawn from the Third-sand—the upper rocks seldom producing, except

where they overlap it along its edges ; (7.) that each one of the three sands produces an oil peculiar to itself, both as to color and gravity—then we have here several important facts, an intelligent consideration of which may materially aid us in our future explorations for oil.

Practical deductions.

By carefully studying the stratification of the group of sands, as above recommended, and noting the quality of the oil in any given well, we ought to be able to assign it its proper position on the belt. If near its axis, we should expect to find the three sands distinctly marked, and the oil of the Oil Creek type ; if north-west of the axis, the First and Second-sands well developed and the Third thin or wanting, with red rocks generally coming in over the First-sand and heavy gravity oil ; if to the south-east, all the sands more or less split up into thin bands, the group as a whole not so thick as on the axis, (owing to the thinning of its under members,) red rocks interstratified all though, and dark oil.

We should also be able to judge by the distance drilled below the First-sand whether the lowest member of the group had been reached. No well should be abandoned without the certainty that *all* of the oil-sands have been pierced, unless other wells in the immediate vicinity have proved the lower sand to be non-productive. Most of the so-called Third-sand wells of Butler and Clarion are only in the upper part of the Third-sand—a band which corresponds in a general way with the oil rocks of Fagundus, Cash-Up, Pithole and Pleasantville. There is still another stratum below and in some localities it will produce oil. Where these localities are the drill alone must determine. Wide areas of this lower rock may be barren, as was the case in the upper districts ; but, no doubt, many good deposits of oil will yet be found in this lower member. A considerable extent of undeveloped territory of this kind will be found in the north-east corner of Butler county, the south-east corner of Venango, and the west end of Clarion.

Necessity of preserving well records.

These are only a few of the possible benefits to be derived from a systematic study of the oil-group, and I earnestly appeal to those who are engaged in sinking oil wells to preserve more accurate and fuller records of their work in the future, for it is upon the drill alone that we must depend for correct information concerning these deeply-buried measures.

Every land-owner should make it a point to preserve at least one complete and reliable record of the drillings on his farm, giving the depth, thickness and character of each stratum from the top to the bottom of the deepest well. This record should be kept from actual measurements, made wherever a change of rock occurs, and recorded on the spot, at the time, in a book kept for that purpose; and not be written up, as is too often the case, when the well is completed, when it is made to conform to some general formula which the driller has worked out from his experiences on other wells.

Contractors and drillers have become so familiar with the general stratification of the country that they see no necessity for noting particularly anything more than the limestone from which to calculate the depth to the oil-sand, the point in the mountain sand to case off the water, and the place for torpedoing the oil sand. "Tell me the distance from the surface to the limestone, in any well, and I will give you the thicknesses and positions of the sands below, and a point within five feet of which the oil-sand will be found," is a very common form of expression among these men when applied to for records of their wells. "We have drilled so much in this territory, and are so well acquainted with the sands, that we know every hour of the day just what stratum we are drilling in, without the necessity of stopping to measure up."

Admitting that this general knowledge of the rocks may be sufficient for all practical purposes in drilling for oil in developed territory it must be apparent that much more definite information is needed when we come to classify the sand —to trace particular bands from place to place—to

ascertain the causes of their variation, and to predict the probable direction of their continuance or the points of their termination.

During the three of four weeks spent in Butler and Clarion last fall I did not succeed in getting five complete and reliable well records, although I sought for them diligently. They have not been preserved as they should have been. Several hundred blanks for filling in the records were distributed personally and by mail, but only a very few of them have been filled in and returned. This should not be so. It is a matter of great public interest and claims an assisting hand from all. One or two well registers from each farm, put on file among the records of the Survey, would form one of the most valuable collections of geological data that could possibly be made. Not only would they be of use in our present investigations of the oil-rocks, but many of them in the lower districts, if properly kept, would furnish the means for an accurate study of the coal seams of those localties not to be obtained in any other way, and not equaled in any other section of the State. Their present and prospective value can hardly be estimated.

We have blanks prepared for keeping these records, and they will gladly be sent by mail to any address on application to the district headquarters at Pleasantville.

McKean and Warren.

It would hardly be proper to close this article without some allusion to the oil fields of McKean and Warren counties, now so rapidly coming into prominence and demanding the closest attention of the oil miner and the geologist.

To both alike these are new and unexplored regions. Only enough is known of them to make it quite certain that they are producing oil in paying quantities from measures several hundred feet below the oil-sands of Venango, Clarion and Butler, and that they are to be developed and studied without any reference whatever to this last named sand group.

At Warren the outcrop of the Venango oil-sands may be seen in the hill-sides above river level, and oil is struck in the wells at a depth of about 600 feet below them. At Bradford, McKean county, the Venango sands have not been recognized, but there is sufficient data to show that if they reached that locality they would there occupy about the same position in relation to the Tunanguant Valley that they do at Warren in relation to the Valley of the Allegheny. The "Tuna" Valley wells are over 1,000 feet deep.

Comparison of oil sands.

Taking the Venango oil-group, then, for our guide, the so-called third sand at Warren lies, say, 600 feet below the Oil Creek third sand; and the so-called Third-sand of Bradford, say 400 feet below the Warren so-called Third-sand.

Here is another illustration of the fallacy of attempting to transfer local names to new fields without an actual tracing of the rocks from place to place.

Any one unacquainted with the Oil-Regions would naturally infer, when reading of our developments, that the third sand of Venango was the same as the third sand of Warren and McKean. But it is here seen that they are three distinct layers of sand, having nothing whatever in common. The third sand of Venango is not represented at all in the wells at Warren, (for they commence to drill below its base,) and neither the third sand of Venango nor the Third-sand of Warren is represented in the wells at Bradford. Why it is considered necessary always to have *three* sands in a well it is hard to conceive, unless it is to convey the impression that the stratification is the same as on Oil Creek—which is a very erroneous idea to go abroad in relation to the oil strata of Warren and McKean. There is certainly no similarity or connection between the oil-rocks of Venango and Warren, and nothing as yet to *prove* any between Warren and McKean.

New fields opened.

In these two districts we evidently have a band of oil-bearing rocks, extending at least to a depth of 1,000 feet

beneath the horizon of the Venango oil-group, entirely dissimilar to the latter lithologically and producing a different quality of oil.

They open up new fields of experiment to the oil producer, new worlds of study to the geologist. All the driller's experiences and all the geologist's researches in the old districts can be of little use here. In age, in structure, in position and in the quality of their oils they have nothing in common.

The finding of oil in these measures is no surprise, for it is well known that in almost every place where the Chemung rocks have been pierced by the drill, some traces of oil or gas have appeared. But what are the peculiar conditions which have resulted in so large a deposit of oil in these localities while so little has been discovered in the same measures elsewhere? This is as much a problem to be worked out *de novo* as was the mystery of the Drake well when first struck in 1859.

In the Venango district we have seen that a sand rock is necessary to insure a paying oil well, and that the direction of the development is determined by the trend of the sand belt. But sands do not seem so effectually to govern the production in these new districts. At Bradford there are several oil horizons, some being in soft shale, and some in rather fine, thin bedded sandstones. In Warren, also, oil is reported in the shales, and the sand is of quite an inferior quality. But this matters not, so that the oil is obtained. A hundred barrel well is a good institution, whether it is in shale or sand, whether the oil comes from one point in the well or accumulates from half a dozen. The old idea of the necessity for three sands should be discarded in these new districts. It is certain that the Oil Creek sands are not there, and what is wanted is *an intelligent study of the rocks as they are found, regardless of their agreement or disagreement with the stratification of Venango or Butler.*

The development has been carried forward so far on certain lines, based on theories formed in following the Venango group. These lines, by chance, may be successful for

a time in certain localities ; but as there is not necessarily any connection between the two systems of oil-bearing rocks, they are probably not the ones which will work out the problem before us.

Note and pursue the geological facts.

It is manifestly to the interest of every well owner in this new territory, to keep good well records and carefully preserved specimens of sand pumpings and to note closely every fact bearing on the geology of the country, in order that a comprehensive understanding of these measures may be arrived at as speedily as possible.

This horizon of the Chemung formation has a wide range throughout the northern counties of this State, and southern New York, and probably contains many other prolific oil deposits, the successful search for which will depend very much upon the use made of the facts revealed by the drill in the districts now being developed.

JOHN F. CARLL,
Assistant.

PLEASANTVILLE, *June 15, 1876.*

CHAPTER VI.

Borings for oil in Jackson and Abbot townships, Potter county.

Notes by Charles A. Ashburner.

A number of wild-cat wells have been drilled in Potter county, with the hope of finding oil. The discovery of the Bradford Oil horizon in McKean county, immediately west of Potter, in 1875, and the rapid growth of this district into what has proved the largest and most prominent of all the oil districts, induced oil prospectors to search for oil in the latter county. The location of but few of these wells was determined by any geological evidence which might warrant the belief that it was even possible to obtain oil where the wells were drilled. Most of these wells have been drilled without the preservation of specimens from the sand-pump, or of written records of the strata which were passed through. Much information which might have been easily gotten, and upon which deductions could have been based as a guide for future development, has in consequence been lost. Each new well has been located in accordance with the arbitrary views of the individual prospector in each case, without any advantage being taken of the experiences of former drillers; a common result has followed in all cases: failure to get oil in any appreciable quantity. In some of the wells however an "oil show" was reported.

It is impossible for the Geological Survey to arrive at any positive conclusion as to the probability or even possibilty of discovering a productive oil-field in Potter county, except on the basis of the facts obtained from the prospect wells when studied in conjunction with facts and experience gotten in drilling in the producing oil districts. A study of the structural and stratigraphical geology of Potter county shows that the geological conditions under which oil has been found in Pennsylvania do not exist generally,

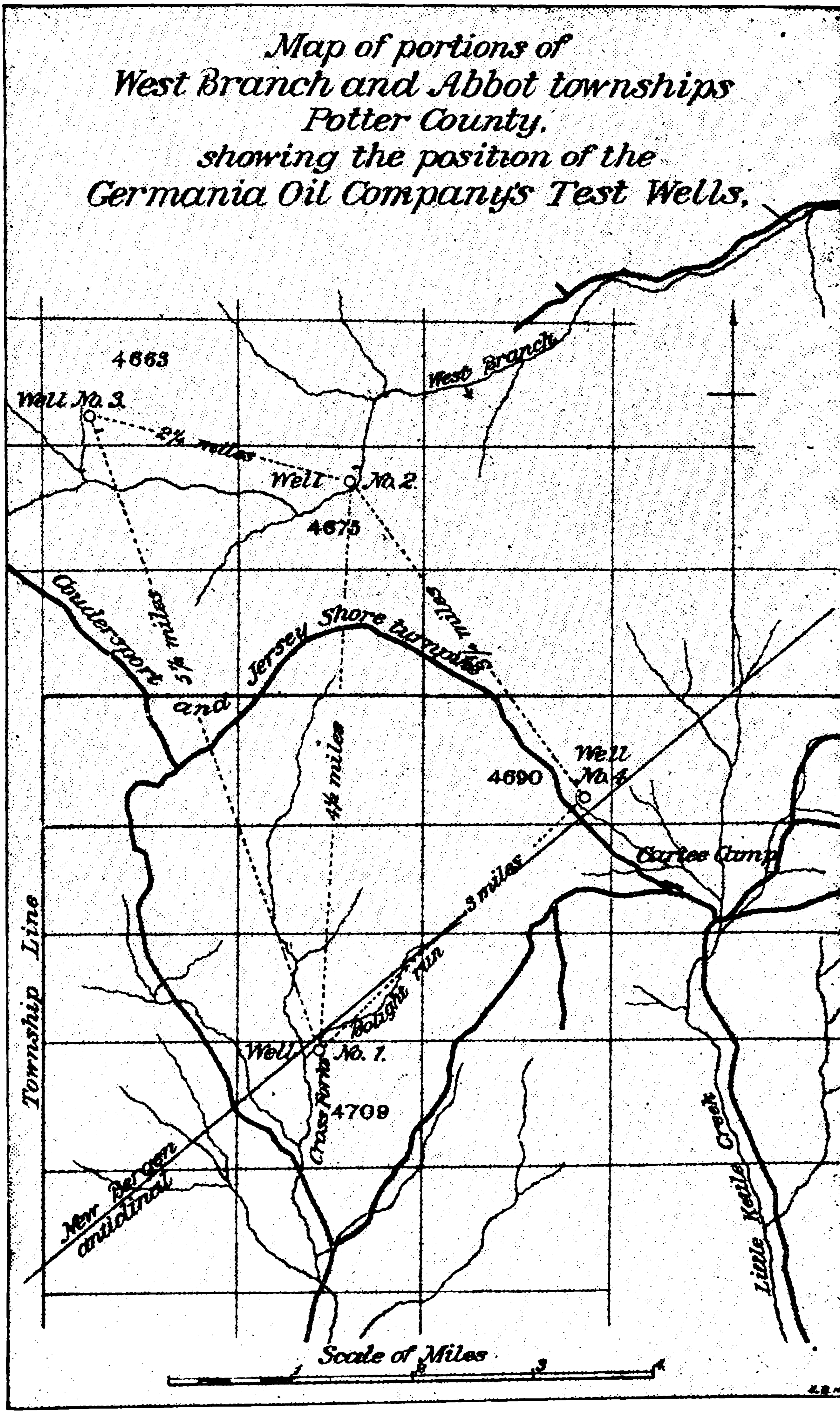
in that county, and the natural inference is therefore that the oil operator has very little hope of finding oil by drilling "wild cat" wells in the county.

It is impossible for the geologist to assert that oil cannot be found in Potter county. If it should exist, however, the conditions under which it would be found would be different from those connected with the occurrence of oil in the producing territories.

At Hebron, about 6 miles north-west of Coudersport, a well was drilled to a depth of 1,286 feet (see Report G^3, page 79); in Harrison township a well was drilled to a depth of 1,995 feet (see Report G^3, page 80.) With the exception of these two records, the only other records which have come into the possession of the Survey, for publication, have been the wells drilled by the Germania Oil Company in the north-western part of Abbot township, and the western part of West Branch township. For records of these wells the Survey is indebted, through Mr. John F. Carll, Assistant Geologist, to Mr. H. C. Ohlen and Mr. J. C. Chambers. The records of these wells have probably been kept more carefully than the records of any other wells which have been reported to the Survey by private individuals in Pennsylvania, and they form a valuable contribution, not only to the local geology, but to the general geology of this part of the State.

The numbers on the left hand margin of the records refer to the numbers of the specimens of the sand pumpings from these wells which were preserved in paper bags; from these bags, small bottles were filled; the specimen in each bottle representing five feet of the well-bore. Thus, by placing the bottles side by side, we get a complete lithological section of the rocks drilled through.

The same numbers on the left hand margin refer to the numbers placed on the bottles, and which are repeated on the bags containing the residue of the specimens. These bags are packed in boxes and stored with the specimens of fossils, &c., belonging to the Survey. See Catalogue, No. 10,735; No. 10,736; No. 10,737; No. 10,738.



Map of portions of
West Branch and Abbot townships
Potter County,
showing the position of the
Germania Oil Company's Test Wells.
West Branch
4663
Well No. 3
2½ miles
Well No. 2
4675
Coudersport and Jersey Shore turnpike
5½ miles
4½ miles
Well No. 4
4690
Carter Camp
3 miles
Township Line
Bought run
Well No. 1
Cross Forks
4709
New Bergen anticlinal
Little Kettle Creek
Scale of Miles
1
2
3
4

Ohlen well, No. 1.

Spring of 1880.

Drilled by Germania Oil Company, on Boligh's run. Warrant No. 4,709, Abbot township, Potter county. Authority, Mr. J. C. Chambers.

Well mouth above ocean in feet,* 1,530

Specimen Numbers.			
	Conductor (no specimens,)	25' to	25'
1- 2.	SS. light gray, fine-grained, ...	10 to	35
3- 10.	Slate, sand, shells and mud, ...	40 to	75
11.	SS. yellowish-gray, fine, ...	5 to	80
12.	Sandy slate, bluish-gray, ...	5 to	85
13.	SS. and sandy shale, fawn color, . . .	5 to	90
14- 15.	SS. shelly, dark-gray, ...	10 to	100
16- 18.	Sandy slate, dark, ...	15 to	115
19.	SS. and shale, *red*, ...	5 to	120
20.	Sand shells, gray, and dark slate, .	5 to	125
	Sand shells, gray, (No. 20½, not bottled,)	3 to	128
21- 22.	SS. fine, flaky, *red*, . . .	7 to	135
	Sand shale, *red*, (No. 22½, not bottled,)	3 to	138
23.	SS. shaly, *dark red*, ...	4 to	142
24.	SS. *reddish-gray*, fine, ...	4 to	146
25.	Sand shale, *red*, ...	4 to	150
26.	SS. *red* and dark-gray, ...	6 to	156
27.	SS. and shale, *red*, ...	4 to	160
28.	Sandy slate, *some red*, ...	5 to	165
29- 37.	Slate, somewhat sandy, ...	45 to	210
38- 42.	SS. dark-gray, slaty, ...	25 to	235
43- 47.	SS. shaly, *reddish-gray and red*, . .	23 to	260
48- 62.	SS. shaly, dark-gray, some slate, . . .	75 to	335
63.	SS. *red* and green, ...	5 to	340
64.	SS. dark-gray, ...	5 to	345
65- 68.	Sandy shale, *red*, ...	20 to	365
69.	SS. greenish-gray, dark, ...	5 to	370
70.	SS. red and dark-gray, ...	5 to	375
71- 73.	SS. dark-gray, fine, flaky, ...	15 to	390
74.	SS. Slaty, *red* and dark-gray, ...	5 to	395
75- 76.	SS. dark-gray, fine, ...	10 to	405
77- 78.	SS. *dark-red* and greenish-gray, fine,	10 to	415
79- 83.	SS. dark, slaty, fine, (No. 82 wanting,)	25 to	440
84- 85.	Sandy slate and *red clay*, ...	10 to	450
86- 89.	Sandy slate and dark clay, ...	20 to	470
	Sand shell, thin, gas, (No. 89½, not bottled,)		
90- 97.	Slate, white sand shells frequent, . .	40 to	510
98-109.	Slate and shells, (No. 107½, at 563', not bottled,)	60 to	570

*Determined barometrically by Mr. Chambers.

110-111.	SS. dark, fine,	10 to	580
112-113.	SS. *light-brown or chocolate*,	10 to	590
114.	SS. gray, fine,	5 to	595
115-116.	Slate,	10 to	605
117-127.	Sand shells and layers of slate,	55 to	660
128-132.	SS. *light-brown or chocolate*,	25 to	685
133-139.	Sandy slate, dark, with sand shells,	35 to	720
140-146,	SS. fine, with layers of slate,	35 to	755
147-203.	Slate, with a few sand shells, (No. 149 to 152 wanting,	285 to	1,040
204.	Sand shells,	5 to	1,045
205-218.	Slate and shells,	70 to	1,115
219-220.	SS. light-gray, fine,	10 to	1,125
221-271.	Slate, with few sand shells,	255 to	1,380
272-275.	SS. dark, slaty, fine,	20 to	1,400
276-280.	Slate,	25 to	1,425
281.	Sand shells, dark,	5 to	1,430
282-283.	Slate, gritty,	10 to	1,440
284-285.	SS. gray, fine,	10 to	1,450
286-288.	Slate, gritty,	15 to	1,465
289.	SS. dark, fine,	5 to	1,470
290-293.	Slate,	20 to	1,490
294-301.	Slate, gritty, and sand shells,	40 to	1,530
302-322.	SS. fine, flaky, with sandy slate,	105 to	1,635
323-329.	SS. fine, but more slaty,	35 to	1,670
330.	Sand shells, with *fossils*,	5 to	1,675
331-339.	Slate and thin sands, (No. 336 and No. 338 wanting,)	45 to	1,720
340-342.	SS. bluish-gray, fine, flaky,	15 to	1,735
343-354.	Slate and slaty sand shells,	60 to	1,795
355-356.	SS. *brownish-gray, fine*,	10 to	1,805
357.	Sandy slate,	5 to	1,810
358.	SS. light, *brownish-gray*,	5 to	1,815
359.	Sandy slate,	5 to	1,820
360-361.	SS. dark, *brownish-gray*,	10 to	1,830
362-380.	Slate and slaty sand shells,	95 to	1 925
381-383.	Slate and shells,	15 to	1,940
384.	Slate,	5 to	1,945
385-389.	Slate and shells,	25 to	1,970
390-401.	Slate and thin slaty sand shells,	59 to	2,029

Cased at 328′. No water below this. Some fetid gas, burning with a dull, smoky flame at 450′, and again at 630′. No show of oil.

Ohlen well, No. 2.

1880.

Drilled by Germania Oil Company on West Branch of Pine Creek, near center of warrant No. 4,675, West Branch township, Potter county. Authority, Mr. J. C. Chambers.

Well mouth above ocean in feet (bar, Chambers,) 1,700

Specimen numbers.				
	Conductor (no specimens,)	45′	to	45′
1- 20.	SS. friable, greenish-gray, *some red*, .	100	to	145
21.	SS. *dark red*, ...	5	to	150
22.	SS. *red*, and dark-gray, ...	5	to	155
23.	SS. *red* and light yellow-gray, ...	5	to	160
24- 25.	SS. *red* and greenish-gray, ...	10	to	170
26.	SS. yellow-gray, fine, hard, . . .	5	to	175
27- 32.	SS. dark-gray, friable, hard in center,	3(	to	205
33.	SS. white and *red*, ...	5	to	210
34- 35.	SS. light-gray, ...	10	to	220
36.	SS. yellow-green, hard, ...	5	to	225
37.	SS. *red*, ...	5	to	230
38.	SS. greenish-gray, ...	5	to	235
39- 40.	SS. *red* and gray, ...	10	to	245
41.	SS. *dark-red*, ...	5	to	250
42- 44.	SS. greenish-gray, ...	15	to	265
45- 48.	SS. gray, ...	20	to	285
49.	SS. *dark red*, friable, ...	5	to	290
50- 55.	SS. *light-red*, or reddish gray, fine,	30	to	320
56- 57.	SS. *red* and gray, ...	10	to	330
58- 72.	SS. *red*, fine but variable in shade and texture, ...	75	to	405
73- 79.	SS. gray, shading on *red*, fine, hard,	35	to	440
80- 81.	SS. *dark-red*, very fine, solid, . . .	10	to	450
82.	SS. *dark-red*, flaky, ...	5	to	455
83.	SS. gray, friable, ...	5	to	460
84.	SS. *red*, flaky, ...	5	to	465
85.	SS. white and yellow, hard, ...	5	to	470
86- 87.	SS. *dark-red*, flaky, ...	10	to	480
88.	SS. gray, ...	5	to	485
89.	SS. *red*, ...	5	to	490
90- 91.	SS. green, *red* and fawn color, ...	10	to	500
92.	SS. dove color, flaky, ...	5	to	505
93.	SS. yellowish, ...	5	to	510
94- 99.	Sand shells, and dark and chocolate-slate, ...	30	to	540
100-103.	SS. gray, fine, compact, ...	20	to	560
104-118.	Sand shells with thin bands of slate,	75	to	635
119-120.	Slate, ...	10	to	645
121-126.	SS. light gray, with layers of slate, . .	30	to	675
127.	Slate, dark, ...	5	to	680
128-129.	SS. light-gray, friable, ...	10	to	690
130-135.	Slate, with some sand shells, ...	30	to	720
136-140.	SS. gray, friable, ...	25	to	745
141.	Slate, ...	5	to	750
142-144.	SS. slaty, dark, ...	15	to	765
145-148.	SS. white, friable, mixed with slate,	20	to	785
149-152.	SS. white and *dark-red*, fine, compact,	20	to	805
153.	Sandy slate, *brownish*, dark, ...	5	to	810

154–155.	SS. white and gray, some slate,	10 to	820
156–158.	Slate, somewhat sandy,	15 to	835
159–161.	SS. *red* and green,	15 to	850
162–163.	SS. buff-color, fine, compact,	10 to	860
164–165.	Sandy slate,	10 to	870
166–171.	SS. gray, friable, micaceous,	30 to	900
172.	Slate,	5 to	905
173–174.	Sand shells, light-gray, with slate,	10 to	915
175–177.	Slate,	15 to	930
178–181.	SS. light-gray, with slaty shells,	20 to	950
182–189.	Slate, somewhat sandy,	40 to	990
190–192.	SS. gray, friable,	15 to	1,005
193–194.	Sandy slate,	10 to	1,015
195–199.	SS. gray, friable,	25 to	1,040
200.	Sandy slate, micaceous,	5 to	1,045
201.	SS. light-gray, shelly,	5 to	1,050
202–203.	Sandy slate, dark, micaceous,	10 to	1,060
204.	Slate,	5 to	1,065
205–207.	Sand shells, gray, with slate,	15 to	1,080
208–212.	Slate,	25 to	1,105
213–222.	Slate and shells,	50 to	1,155
223.	Sandy slate, *red* and green,	5 to	1,160
224–226.	SS. and slate, both dark,	15 to	1,175
227–242.	Slate, sand shells and mud rock,	80 to	1,255
243–247.	SS. and slate, fawn color, micaceous,	25 to	1,280
248–253.	Slate,	30 to	1,310
254–255.	SS. and slate, dark,	10 to	1,320
256.	Slate,	5 to	1,325
257–258.	SS. slaty,	10 to	1,335
259–265.	Slate,	35 to	1,370
266–267.	SS. *brownish*, fine, flaky, micaceous,	10 to	1,380
268–293.	Slate, with infrequent sand shells,	130 to	1,510
294–298.	Slate and shells,	25 to	1,535
299–326.	Slate,	140 to	1,675
327–329.	Sand shells and slate,	15 to	1,690
330–341.	Slate to bottom of well,	60 to	1,750

Cased at 520′. No water below this. Some gas at 550′, similar to that in No. 1. No show of oil.

Ohlen Well, No 3.

1880.

Drilled by the Germania Oil Company, on a small tributary of West Branch of Pine Creek, in the south-west quarter of Warrant No. 4,663, West Branch township, Potter county. Authority, Mr. J. C. Chambers.

Specimen Numbers.				
	Well mouth above ocean in feet (bar., Chambers)			2,050′
	Conductor, &c.,—(No specimens)	40′ to	40′	
1– 6.	SS. yellow-gray, fine, hard,	30 to	70	

7- 12.	SS. Shaly, with fawn color and *red slate*,	30 to	100
13.	SS. gray,	5 to	105
14- 15.	SS. *red* and dark-gray, fine, mica,	10 to	115
16- 22.	SS. gray, shelly,	35 to	150
23- 29.	SS. gray, shelly,	35 to	185
30- 31.	SS. gray, shelly, (Nos. 30, 31, 31½),	15 to	200
32- 35.	SS. fine, hard, argillaceous,	20 to	220
36- 37.	SS. and chocolate sandy shale,	10 to	230
38- 39.	SS. shelly, gray,	10 to	240
40- 46.	SS. fine, dark-gray,	35 to	275
47- 51.	SS. shelly,	25 to	300
52- 55.	SS. shelly, *red*,	20 to	320
56.	SS. gray,	5 to	325
57- 60.	SS. *red*, fine grained,	20 to	345
61- 64.	SS. shells and slate,	20 to	365
65- 74.	SS. *red* and gray,	50 to	415
75- 79.	SS. gray, some slate,	25 to	440
80- 87.	Sandy slate, *red* and green,	40 to	480
88- 89.	SS. greenish-gray,	10 to	490
90- 94.	SS. *red* and green,	25 to	515
95- 96.	SS. greenish-gray,	10 to	525
97.	SS. *red* and green,	5 to	530
98- 99.	SS. gray,	10 to	540
100.	SS. *red* and green,	5 to	545
101-102.	SS. gray, fine,	10 to	555
103.	SS. *red* and green,	5 to	560
104-105.	SS. gray,	10 to	570
106.	SS. bluish-gray, dark, fine,	5 to	575
107-124.	SS. yellow-gray, fine, hard,	90 to	665
125-126.	SS. bluish-gray, friable,	10 to	675
127-132.	SS. yellow-gray, with slate,	30 to	705
133-135.	SS. green-gray,	15 to	720
136-137.	SS. green and *red*, shaly,	10 to	730
138-144.	SS. greenish-gray,	35 to	765
145-151.	SS. greenish-gray, fine,	35 to	800
152-153.	SS. gray, mixed with *red*, shaly,	10 to	810
154-155.	SS. gray, fine,	10 to	820
156-157.	SS. gray and *red*,	10 to	830
158-161.	SS. greenish-gray, fine,	20 to	850
162-163.	SS. gray and *red*,	10 to	860
164-171.	SS. *red*, shaly,	40 to	900
172-176.	SS. yellow-gray, fine,	25 to	925
177-181.	SS. gray, fine,	25 to	950
182.	SS. gray, very fine and hard,	5 to	955
183-189.	SS. *light-red*, fine, hard,	35 to	990
190-197.	SS. and shale, *dark reddish brown*,	40 to	1,030
198.	SS. *dark red* and white,	5 to	1,035
199-201.	SS. *red* and white, fine,	15 to	1,050
202.	SS. yellow-gray, fine,	5 to	1,055
203.	SS. *red* and white,	5 to	1,060
204-208.	SS. yellow-gray,	25 to	1,085

209-211.	SS. *red*, shaly,	15 to 1,100
212-213.	SS. yellow-gray,	10 to 1,110
214-219.	SS. *dark red*, micaceous, flaky,	30 to 1,140
220-222.	SS. yellow-gray, fine,	15 to 1,155
223.	Slate, dark, and gray shells,	5 to 1,160
224-225.	SS. gray with dark slate,	10 to 1,170
226.	Slate, dark,	5 to 1,175
227-229.	SS. yellow-gray, fine, hard,	15 to 1,190
230-234.	Sand shells and dark slate,	25 to 1,215
235-237.	Slate, dark,	15 to 1,230
238-243.	Sand shells, micaceous, light-gray, with slate,	30 to 1,260
244-246.	Slate, muddy,	15 to 1,275
247-249.	Slate, mud rock and shells,	15 to 1,290
250-251.	Slate, mud rock and shells,	10 to 1,300
252-255.	Slate,	20 to 1,320
256-260.	Slate and shells,	25 to 1,345
261.	Sand shells and slate,	5 to 1,350
262-276.	Slate, sandy,	75 to 1,425
277.	Slate, dark, clean,	5 to 1,430
278-279.	Slate and fossilliferous sand-stone layers,	10 to 1,440
280-281.	Slate, dark,	10 to 1,450
282-284.	Sand shells, fossilliferous,	15 to 1,465
285-288.	SS. micaceous, flaky, *red*,	20 to 1,485
289-294.	SS. *red* and dark slate,	30 to 1,515
295-299.	SS. brownish, flaky, fine,	25 to 1,540
300-306.	Sandy shale, *dark reddish brown*,	35 to 1,575
307-309.	Sandy shells, light and dark slate,	15 to 1,590
310-311.	SS. *brown*, with light gray shells,	10 to 1,600
312-327.	SS. dark-gray, slaty,	80 to 1,680
328-334.	Sand shells, gray, with slate,	35 to 1,715
335-340.	Sand shells, gray and *brown*, with sandy slate,	30 to 1,745
341-343.	Sand shells, gray, with slate,	15 to 1,760
344-355.	Sand shells, light-gray, with less slate,	60 to 1,820
356-359.	SS. *light brown and red*, micaceous, flaky,	20 to 1,840
360-375.	Slate and shells,	80 to 1,920
376-379.	SS. *light-brownish-gray*, micaceous, flaky,	20 to 1,940
380-384.	Slate, micaceous,	25 to 1,965
385.	SS. *brownish-gray*, flaky,	5 to 1,970
386-389.	Slate,	20 to 1,990
390.	Sand shells and slate,	5 to 1,995
391-421.	Slate,	155 to 2,150
422.	Slate, sandy,	5 to 2,155
423-434.	Slate, upper part muddy, (Nos. 434 and 435. each 10'.)	75 to 2,230
	"This well was afterwards drilled deeper and no specimens kept, but there was 'no change in the character of the drillings in this interval'" of,	520 to 2,750

Cased at 632′. Salt water at 550′. No water below the casing, no gas, no oil. The well was torpedoed dry at about 1,820′. The shot threw stones out of the well but caused no water, oil, or gas to come in. On running the bailer the hole was found to be perfectly dry.

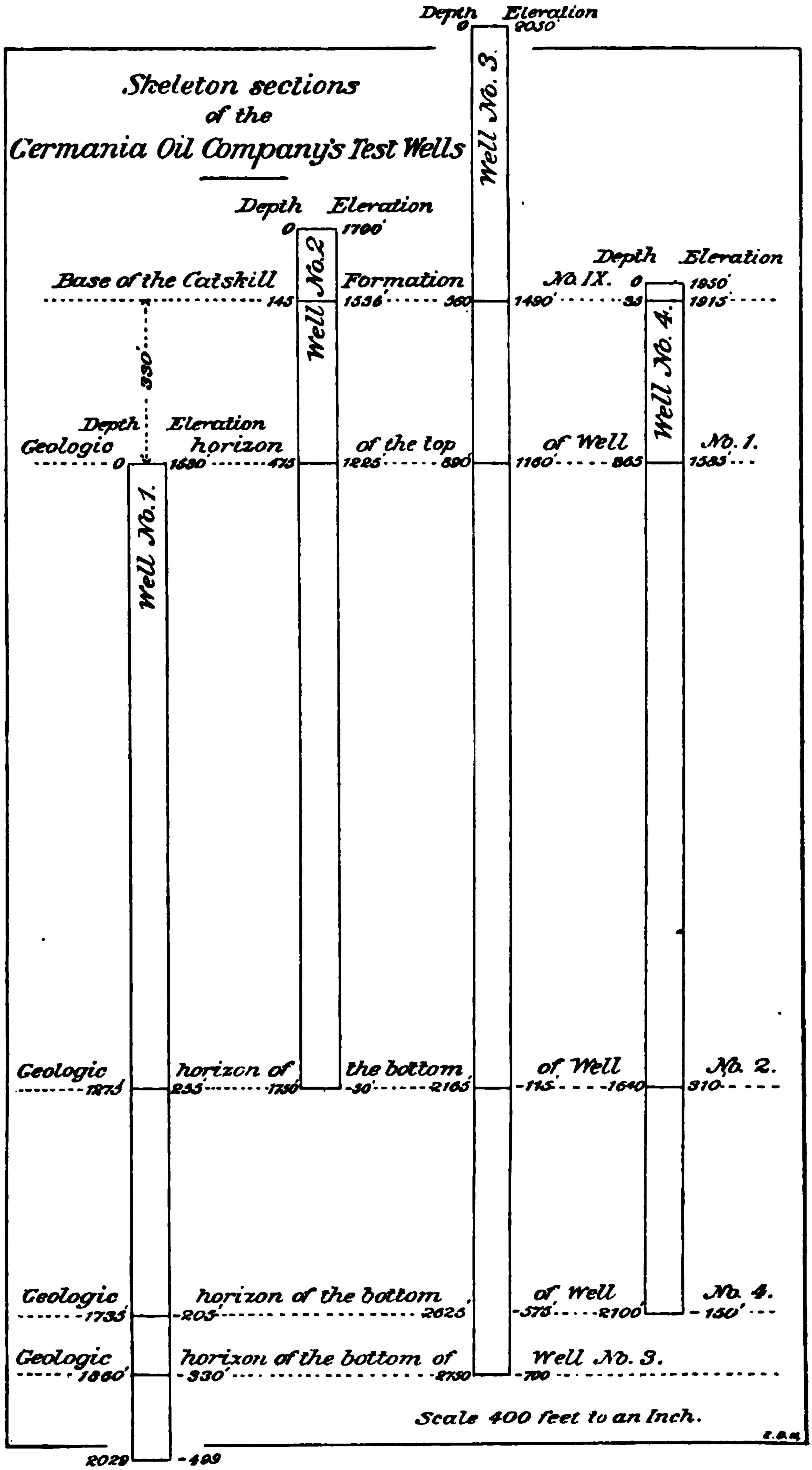
Ohlen Well, No. 4.

1880–81.

Drilled by Germania Oil Company, near Carter Camp, in the south-east corner of Warrant No. 4,690, Abbott township, Potter county. Authority, Mr. J. C. Chambers.

Well mouth above ocean in feet, (bar., Chambers,) . . . . . . 1,950′

Specimen Numbers.			
	Conductor, (spec. 1 and 2 wanting,) . .	10′ to	10
3– 5.	Shale, *red*, ...	15 to	25
6– 7.	SS. *red*, ...	10 to	35
8– 18.	SS. yellow-green, yellow and drab, fine,	55 to	90
19.	SS. *red*, fine, compact, ...	5 to	95
20.	SS. dark bluish-gray, friable, . . .	5 to	100
21.	SS. *red and reddish-gray*, friable, . .	5 to	105
22.	SS. *red*, micaceous, ...	5 to	110
23.	SS. gray, ...	5 to	115
24– 27.	SS. fine, *with red shale*, ...	20 to	135
28– 29.	SS. *light-red and reddish-gray*, ...	10 to	145
30.	SS. *red*, friable, micaceous, . . .	5 to	150
31– 37.	SS. greenish-gray, friable, micaceous, .	35 to	185
38.	SS. fine, compact, with shale, *light red*,	5 to	190
39– 42.	Sandy slate, dark, *purplish*, ...	20 to	210
43.	SS. white and gray, . .	5 to	215
44– 50.	Slaty SS., variable in composition and color, dark, ...	35 to	250
51.	SS. light-gray, *a little red*, ...	5 to	255
52– 55.	Sandy slate, dark, ...	20 to	275
56.	SS. light-gray and *red*, friable,	5 to	280
57– 59.	SS. dark and light, friable, micaceous, .	15 to	295
60.	Shaly sandstone, *red*, . .	5 to	300
61– 84.	Sand shells, gray, with dark slate, . . .	120 to	420
85– 94.	SS. light *brownish-gray*, friable, micaceous, ...	50 to	470
95–102.	SS. *reddish-brown* and gray, with *red shale*, . . .	40 to	510
103–107.	SS. dark-gray, with purplish slate, micaceous, . . .	25 to	535
108–109.	SS. chocolate and gray, fine, friable, micaceous, ...	10 to	545
110–123.	SS. dark-gray, with dark sandy slate, micaceous, ...	70 to	615
124–126.	Slate, ...	15 to	630
127–140.	Slate and sand shells, ...	70 to	700



Skeleton sections of the Germania Oil Company's Test Wells
Well No. 1.
Well No. 2
Well No. 3.
Well No. 4.
Depth
Elevation
Base of the Catskill Formation
No. IX.
Geologic horizon of the top of Well No. 1.
Geologic horizon of the bottom of Well No. 2.
Geologic horizon of the bottom of Well No. 4.
Geologic horizon of the bottom of Well No. 3.
Scale 400 feet to an Inch.

141-148.	SS. dark-gray and *red*, with sandy, micaceous slate,	40 to	740
149-155.	Sand shells and slate,	35 to	775
156.	SS. light-gray, fine,	5 to	780
157-159.	SS., gray shells and slate,	15 to	795
160-170.	Sand shells, *chocolate*, fine, with dark slate,	55 to	850
171-181.	Slate, with some fine sand,	55 to	905
182.	SS. light-gray, fine, close,	5 to	910
183-196.	Slate,	70 to	980
197-210.	SS. light-gray, fine, flaky, some slate,	70 to	1,050
211-234.	Slate, with a little fine *brown sand*,	120 to	1,170
235-239.	SS. *brownish*, fine, some slate,	25 to	1,195
240-253.	Sandy slate,	70 to	1,265
254-266.	SS. gray, light and dark, fine, flaky,	65 to	1,330
267-293.	Slate,	135 to	1,465
294-300.	Slate and shells,	35 to	1,500
301-306.	Slate sandy, micaceous,	30 to	1,530
307-313.	SS. light-gray,	35 to	1,565
314-326.	Sandy slate,	65 to	1,630
327-348.	SS. in layers, gray and variable, with sandy slate,	110 to	1,740
349-364.	Sandy slate,	80 to	1,820
365-372.	SS. dark-gray, fine, some slate,	40 to	1,860
373.	SS. ocher color, fine, hard, fossils,	5 to	1,865
374-386.	SS. dark, fine, slaty,	65 to	1,930
387-420.	Sandy slate, granulated, very uniform to bottom of well,	170 to	2,100

Cased at 530.′ No water below this. No oil, no gas.

The records of these wells I have carefully studied, in conjunction with other data collected by the Survey in Potter county, and I have been enabled to arrive at some general conclusions as to the relationship existing between the strata in the individual records.

The specimens of the sand pumpings, taken from these wells were not accessible at the time that this report was prepared for the press, so that some of the conclusions stated here may be slightly modified by a subsequent study of the specimens, in conjunction with a more detail examination of the surface geology, on the ground.

What appears to be the bottom of the Catskill formation, No. IX, as referred to in reports of McKean, Cameron, Elk and Forest counties, (see reports R and RR) was passed through in well No. 2 at a depth of 145 feet, in well No. 3 at a depth of 560 feet and in well No. 4 at a depth of 35

feet. At well No. 1 this same geological horizon is about 330 feet above the top of the well mouth, or in other words, the geological strata occurring on a level with the top of well No. 1, was found in well No. 2 at a depth of 475 feet, in well No. 3 at a depth of 890 feet, and in well No. 4 at a depth of 365 feet. From this it is perceived that although well No. 1 was not drilled as deep as either wells Nos. 3 or 4, yet the lowest rock geologically, was pierced by well No. 1. To penetrate the same geological horizon as that at the bottom of well No. 1, well No. 2 would have to be drilled 754 feet deeper, well No. 1, 169 feet deeper and well No. 4, 294 feet deeper.

From these conclusions, and the elevations given for the mouth of each well, the dip of the strata between the different wells has been estimated as follows:

Well No. 4 to well No. 1, distance 3 miles, total dip 55 feet.
Well No. 4 to well No. 2, distance 3¼ miles, total dip 360 feet.
Well No. 2 to well No. 3, distance 2¼ miles, total dip 65 feet.
Well No. 1 to well No. 3, distance 5½ miles, total dip 370 feet.

Wells Nos. 2 and 4 are located very near the axis of the New Bergen anticlinal, and wells Nos. 1 and 3 near the Mill Creek and Pine Creek synclinal, which is the north-eastern extension of the Wharton Coal-basin in south-western Potter county, and of the Cameron Coal-basin in Cameron county, both of which are parts of the Fourth Bituminous Coal-basin.

No carefully measured section has been made of the outcropping strata in either Abbot or West Branch townships, but sufficient data have been obtained to conclude that formations Nos. X, IX, and VIII are thicker in this part of the county than in that part of the county immediately adjoining McKean and Cameron counties.

It is not possible to locate the horizon of the Bradford oil-sand in any of these well records, nor do I believe that the Bradford oil-sand was ever deposited in the area where these wells have been drilled.

Although wells drilled in Potter county can never be expected to add anything to our oil production, their records are invaluable additions to our geological knowledge of the region.

ON THE VEGETABLE ORIGIN OF COAL.

BY LEO LESQUEREUX.

The assertion that coal is a compound of vegetable remains would be contradicted by very few if any living naturalists, supported as it is by the following proofs:

1. By the abundance of well-preserved fragments of plants generally found in the roof shale of the coal strata, or at their base; in the fire clay, or in the layers of clay shale (clay partings) at divers parts of their thickness. This fact is known by every one who has had opportunity to examine seams of coal.

2. By the distribution of microscopic fragments of vegetables throughout coal, however deformed the fragments may have become by maceration and compression.

3. By chemical analysis.

These three lines of argument may be developed in the following manner:

Antoine de Jussieu, the father of the French botany, returning from Spain in or about 1740,* found along the river of Gies, near St. Chaumont, a quantity of fragments of plants which he says are varied and far different from the plants living in France. He remarks that the impressions marked upon the stones represent true plants; the specimens are always laying flat like plants in an herbarium. They cover the surface and become more black and more bituminous when nearer to the layers of coal. The reasoning on those plants by Jussieu is very ingenious. In looking for their origin, he says, they seem to represent the vegetation of a warm climate, and he is disposed to admit the opinion of Bernard Palissy that they were brought by

*The date is not quoted. Antoine de Jussieu was born in 1686; died in 1758. La formation de la houille, by Saporta: Revue des deux mondes. 1st Dec. 1882.

water. The sea has covered the continents; the currents have carried and deposited the plants and the shells which are now found petrified.

In 1769, Valmont de Bomarre believed that the coal was of vegetable origin, admitting as cause the burial of forests of resinous trees, resulting from catastrophies to which our globe was subjected.

In 1778, Buffon says that coal beds have originated from the first plants which our earth has produced. Water still tepid covered the greatest part of the earth, excepting a few low lands, which were first inhabited by an immense amount of plants and trees, of which the debris transplanted to divers places have formed deposits of vegetable matter at distant points.

Beyond the information obtained from subsequent researches on the mode of proceedure of nature in procuring, heaping and preserving the materials, science now says nothing more but what the old botanists have asserted—coal strata are formed by remains of vegetables.

Since Buffon, geologists and paleontologists have tried to explain more fully and more clearly the formation of coal, and have begun of course the study of the plants found in connection with coal. Blumenbach and Schlotheim in Germany first, in the beginning of the century; then Sternberg in Germany and Brongniart in France, published at the same time, 1820, the results of their learned researches; and since then the number of phytopaleontologists has increased in Europe and America; and from their works we know that the Flora of the Carboniferous period is the most interesting of all those which have appeared upon the earth during the different epochs or periods of time which successively contributed to the formation of the surface of our globe before the appearance of man.

It would be a useless task to name all the botanists who have given their time to the study of the coal plants.

The number of private collections, of public institutions and museums where specimens of coal plants are now preserved is beyond computation. All the students of this

splendid flora, without exception, acknowledge that the coal has evidently been formed by remains of plants, of the same kind as those which are found especially in the roof shale of the coal beds, sometimes also in the clay of the bottom, in such a perfect state of preservation that the character of the ancient vegetation, the names of its species, their reference to families and genera, have been studied nearly as satisfactorily as it would have been done were they the plants of our epoch.

First Objection.—The vegetable remains found in and upon the shale of coal beds do not prove that the coal itself is a compound of plants. The preserved remains may have been deposited and indeed have been deposited in the shale after the formation of the coal. Therefore leaves, branches, fagments of plants of diverse nature, like pieces of bark, etc. found now in connection with coal beds, may have been carried by atmospheric disturbances, storms, etc. and strewn upon layers of bituminous matter, like the lakes of bitumen observed in the vicinity of some volcanoes. The plants. therefore, may be totally foreign to the composition of the coal.

Answer 1.—In examining seams of coal covered by shale bearing plants, one sees that the roof shales become gradually more bituminous in approaching the line of connection with the coal; and that even where they have become quite black, or half shale and half coal, the remains of plants are still recognized, losing their forms only when the matter is entirely decomposed or reduced to hard coal. But even then, in some coal beds, the thin layers of nearly pellucid very hard bituminous matter are separated by their lamellæ of charcoal, evidently woody matter. Leaflets of ferns, and pieces of bark with their peculiar leaf-sears, are often printed with a perfect preservation of their forms and of their nervation, easily distinguishable with the eye.

Answer 2.—In some coal beds of cannel, or very bituminous coal, fragments of plants of divers size, trunks of trees, branches of ferns, especially small seeds, spores (the seeds of Lycopodiaceæ) are found, sometimes in great

abundance. Species of coal in England have been found composed of spores in such profusion that some authors have hazarded the opinion that coal has been entirely formed of spores. In the cannel coal, the most compact coal of which the matter has been so thoroughly decomposed that the fracture of the substance is as smooth as that of black marble, for example in the Breckenridge coal of Kentucky, one finds large stems, *stigmaria*, *lepidodendron*, *etc.* whose forms are perfectly preserved as sulphide of iron or pyrites. At Cannelton, the bed of coal, also cannel, rests upon a layer of less thoroughly decomposed matter, but still coal, wherefrom the remains of 250 species of plants have been obtained and described.

Objection continued.—But, the objector may say, bitumen either deposited by and from the atmosphere or by the eruption of volcanoes may have been distributed upon forests or upon land covered with a varied vegetation ; and of course the remains of plants might thus be found at the base of the bituminous deposits; or, pieces of wood, branches, trunks, large fragments of bark, may have been thrown from the borders during the process of accumulation of the matter without having contributed in any essential manner to the composition of the combustible. And, from this objection, we may estimate what a high degree of imaginative power it would be necessary to exercise ; what a number of hypotheses, it would be necessary to put forward to explain the composition of coal merely as bitumen ; that is, for setting aside the evidence offered by the fossil remains of plants visibly and distinctly preserved above, below and within the coal. How much farther will the hypothetic mind have to go in order to explain most of the other features of the coal beds, their distribution, their stratification, their geological affinities, etc ?

Answer 3.—Now we have for answering the preceding objection a kind of evidence concerning the true nature of coal to which it seems that no contradiction can be reasonably offered. By the work of the lapidary it is possible to obtain lamellæ of coal thin enough to be rendered nearly translucent. On subjecting these thin lamellæ to the micro-

scope, one may easily see the matter of the coal to be composed of mere fragments of vegetables, though they may be deformed by compression and decomposition. Researches of this kind have been for some time actively pursued, and have proved that a piece of coal taken from any part of a coal seam, either in vertical or horizontal direction, is entirely made up of very small fragments of plants mixed of course with an amount of bitumen such as necessarily, results from the decomposition of plants. Researches on this subject have been pursued in Germany by Gumbel *; in France by Renault †; in England by Williamson, ‡ Carruther, Wethered ‡; in Switzerland by Früh §; in North America by Dawson. All have arrived at the same conclusion, that the coal is entirely composed of vegetable remains. The more recent researches of Prof. Wethered of London have been upon pieces of coal taken at various heights in vertical sections of coal beds and also at different horizontal distances. From these specimens, thus selected in series, slices have been prepared for microscopic examination and the results have been published with figures. In order to show the mode of procedure and the value of the researches I quote one of the sections.

Section of the Four-feet seam. Colliery near Pontypridd, South Wales:

Description.		*Structure.*
Coal, (top bed) brittle, bright luster,	2′ 0″	Carbonized vegetable tissue with a little hydrocarbon.
Argillaceous parting, ...	1′ 0″	Miniature under-clay. *Stigmaria.*
Coal, (middle bed) medium luster,	4′ 6″	Highly carbonized vegetable tissue.
Argillaceous parting, ...	0′ 5″	Miniature under-clay.
Coal, (lower bed,)	2′ 0″	Well-preserved *scalariform tissue*, close under the parting; and beneath, *spores* and *spore cases*, with other vegetable substances.

* Breiträge zur Kentniss der Textur verhaltnisse der Mineral Kohlen, Munich, 1883.

† Notes pour servir a l'histoire de la formation de la houille (in four separate pamphlets). Comptes rendus 1883.

‡ On the structure and origin of carboniferous coal seams. Proc. Geol. Soc. London, May, 1885.

§ Ueber Torf und Dopplerit, Zurich, 1883.

In other sections the composition varies. Thus, in the splint coal seam, Whitehill colliery, near Edinburg, the author finds in the upper part (1′ 10″ thick) a mass of macrospores, microspores and fragments of spore cases. In the rough coal below it measuring 0′ 10″, he finds in the bright layers hydrocarbon with a few spores and, in the dull layers spores of different variety to those in the splint coal above. In the lower splint (0′ 4″) showing dull and bright layers he finds in the dull layers a mass of macrospores and microspores, while the bright layers are made up of hydrocarbon without spores.

It cannot be said against these revelations of structure made by the microscope that the so-called carbonized vegetable tissues may not be plants; for the celebrated anatomist Renault, of the Museum of Paris, remarks, as others have noticed before him, that in a great number of cases, the remains of the plants which compose the coal, although deformed by maceration, still show recognizable organic structures, and may be identified as plants of the same species as those which are found in fragments silicified, or in the roof shale, where they have been protected against deformation by being embedded in clay, iron, sand, etc.

The thin layers of hydrocarbon are produced of course by the decomposition of the vegetable tissue and by compression. They are rarely pure but generally mixed with spores or pieces of cellular tissue, isolated cells, etc.

To the evidence thus obtained directly by the eyesight of observers may be added the no less direct evidence of chemical analysis. The proportion of ashes remaining after combustion of coal is on an average the same as that of various species of wood. If there is a little surplus in the proportion it is easily accounted for, as caused by the introduction into the original mass of that dust of mineral matter reduced to powder always carried by the wind.

And, in regard to the constituents of the coal, chemistry acknowledges that they must positively be a result of the slow, gradual and long-continued decomposition of vegetable matter, protected from the free access of the air and its burning element, oxygen.

The process of this peculiar decomposition has been followed from its beginning in peat, to its first more advanced stages in the lignite of the glacial era; in which latter form the branches and trunks of trees have already become softened to the consistance of soap without losing their color; then, to the next stage of miocene lignite, in which the wood, still soft, is already quite black; then, to that of lower tertiary or upper cretaceous coal, where the vegetable matter is hard and compact like coal, but easily disaggregated by atmospheric action; then, to coal of the carboniferous period; and finally, to the condition of anthracite. The whole series forms an unbroken chain of successive modifications, which not only can be but has been carefully studied, and recorded as one of the most interesting pages of the secret work of nature.

But granting that the composition of coal is purely vegetable the problem of its formation is not yet fully solved. Objectors have proposed a number of questions which have to be considered, in order that the procedure be fully understood.

1st. How is it possible that plants, even woody plants or trees, could have been heaped by natural agency in such a way that the original material could have produced, after decomposition and compression, beds of coal from 4 to 25 feet or even more in thickness?

To answer this most important query some have supposed that forests have been prostrated by some catoclysm, and being afterward covered by the sea the wood has been gradually transformed into coal.

But a whole forest, however dense, could not possibly produce after transformation to coal a layer more than a few inches thick.

2d. Others have supposed that the woody material of vegetation growing along the borders of great rivers has been carried by water for long years, deposited near the mouth of the rivers, there heaped together, then covered by mud and sand, and buried for future decomposition and transformation into coal.

But this mode of procedure is contradicted by the pur-

ity of the matter composing coal. In such an operation the vegetation would be mixed with foreign elements, mud, sand, etc. Beds of lignite have indeed been formed in the Red river and in some of the affluents of the Mississippi near its mouth; but lignite of this kind is always a combustible of little value; its proportion of ash being 50 per cent. or more.

3d. The celebrated German chemist Bishoff supposed that the materials carried by currents into the sea were gradually deposited according to their weight; first, the heavy sandy parts; then the finer mud above it, this forming the under clay of a coal bed; afterward the heaviest portion of the woody matter; and finally, the lightest portion, by itself, to form the top or upper coal. But this hypothesis, ingenious as it may appear, does not account for anything we know of the structure of a coal bed, the composition of which in a general way is the same throughout. While the stratification in horizontal layers is perfectly distinct, there is no succession of various kinds of deposits, such as would of course have taken place had the bed been produced by the translaation of mixed materials from land surfaces into the sea.

4th. The French naturalist Grand 'Eury has lately proposed a new hypothesis for the process of accumulation of woody materials in the formation of a coal seam. He supposes that there were at the carboniferous period shallow lakes or ponds surrounded by great forests of very luxurious vegetation and that the debris of these forests, small branches, leaves, especially the bark of trees, already half decomposed or dried by atmospheric action, were swept by heavy rains into these low grounds; where, being gradually heaped together, they contributed an amount of woody matter sufficient for making a coal bed. These materials, being covered by foreign deposits in the sea were gradually transformed into coal by the chemical process of slow combustion.

Such an hypothesis could scarcely be worth considering, even if the coal strata were all confined to basins of very small extent, say one or two square miles, or less. For,

those who have observed the process of decay in the thickest parts of our woods know well enough that the greatest amount of rain effects no such displacement of the decaying fragments of vegetation, but on the contrary serves only to compress them, and make them adhere more closely to the ground. Currents only are able to carry the debris out of the forest; but currents do not carry off merely the woody fragments, but the earthy matter, mud, sand and gravel also. But, even supposing the most favorable circumstances for such displacement of woody materials and for their successive accumulation in shallow basins, how would this account for the accumulation of vegetable matter with a uniform thickness over such extensive areas as those now occupied by some of the coal-beds of North America, the Pittsburgh coal bed for example, which spreads without interruption through many thousand square miles of country?

5th. The Vail hypothesis imagines that coal was merely a local accumulation of bitumen derived either from the earth by volcanic action, or gradually condensed from a fancied bituminous atmosphere, encircling our planet, like the rings of Saturn.

Bitumen has indeed issued from the earth and has been mined, under the name of albertite, &c, but not in horizontal strata, but in more or less irregular and more or less vertical veins in no respect resembling coal beds. And the evidence is conclusive that its origin is to be ascribed to outflows of petroleum, through open fissures, which was afterwards transformed into a hard black compact, more or less translucent substance, highly prized in the manufacture of gas, very rich in volatile hydrocarbons, flaming and smoking freely, but not at all resembling ordinary gas coal, being pure bitumen and without a trace of vegetable fiber to be detected in it.

This absence of vegetable remains is also quite enough to disprove any theory which would derive the bitumen of a coal bed from a bituminous atmosphere, even if it were possible to admit such an idea in the absence of all evidence.

6th. The last hypothesis worth mentioning on the subject is that of the formation of coal by the accumulation of marine plants whose vegetation is sometimes prodigious. Everybody knows something about the great floating fields of *sargassum*, which cover immense areas of the surface of the Atlantic ocean, and are in places thick enough to impede navigation. This theory admits that the coal has been formed of vegetable remains only; but it leaves out of view that the plants which compose coal are woody or fibrous; whereas, marine vegetables have no fiber, no wood, being merely cellular tissue. Moreover, their decomposition is rapid, as well when protected against the oxygen of the air, as when fully exposed to it. They are soon transformed into a fluid black matter which penetrates the sand along the shore. They may have produced the oil and gas deposits, but could not have produced coal.

The celebrated German physicist Dr. Otto Kuntze, recognizing the unsoundness of the last hypothesis, knowing at the same time the extraordinary luxuriance of the marine vegetation, and feeling the necessity to account for its purpose and its development in the plan of nature, has ingeniously modified the theory so as to render it less objectionable.

He supposes that on the debris of a very active floating marine vegetation, whose surface had become gradually solid enough to support aërial plants, a different kind of vegetation gradually established itself. First aquatic plants which, living partly immersed in water, partly exposed to the atmosphere, and therefore composed of woody tissue, appeared upon this still floating substratum. Then came large floating stems, the stigmaria, rendering the ground more solid. Then shrubs and large ferns grew up; and then trees of different kinds. These growths accumulated after a while, formed a mass so heavy that it gradually sank lower and lower into the sea, but so slowly that the vegetation still continued at the surface of the water, supported on successive layers of dead material, until the whole stratum escended to the bottom of the sea, to be there covered over

by aqueous sediments and transformed into coal by the slow process of combustion. At first sight, this hypothesis is attractive, for it accounts for some things in the structure of the coal; as, for example, that gradual sinking of the woody materials which the succession of the coal measures proves to have taken place: the immediate superposition of a bed of limestone upon a coal bed, in some places, etc.

The theory has however one marked deficiency; for it fails to give any explanation of a most important point, viz: the formation of the clay-beds which generally, if not always, serve as bottoms or supports to the coal-beds. Moreover, it does not account for the origination of land plants on the surface of a marine vegetation floating in the middle of an ocean. Nor does it give any explanation for the universal conformability of the coal-beds to the intermediate strata, etc. It is therefore nothing more than a fanciful hypothesis; but, as it is the most rational of all those which have been proposed, it makes it clear that to come to an understanding of coal, we must cease to indulge the hypothetical mood, and ask from nature herself an explanation of her proceedings.

Everybody knows something, at least from hearsay, about what is called the *peat bog theory.* But what is a peat bog?

In this country where peat deposits are comparatively scarce, and are mostly covered by meadows or forests, and where, if they are not wholly unknown to naturalists, they have never been explored except by persons who were interested merely in their money value as fuel, it will be worth while to describe their formation with some detail. The definition of a bed of peat is the same as that of a bed of coal. It is an accumulation of remains of plants grown *in situ*, whose remains, deposited each year, or after the cycle of their vegetation is completed, are superposed without interruption, one layer upon another, until the accumulation becomes sometimes of great thickness, and covering a wide surface of land. Lest this definition be taken as a mere assertion, and to make it worthy of belief, it is

necessary to explain the process of *peat growth*, and exhibit its more important phases and results.

Two conditions are necessary for the origin and growth of peat, water either stagnant in basins, lakes, pools, etc., or water abundantly supplied by a boggy atmosphere, increased by dense forest growth.

Pools of stagnant water when not exposed to periodical drying up, are invaded by a peculiar vegetation, first mostly composed of *confervæ*, simple thread-like plants, of various color and of prodigious activity of growth, mixed with a mass of infusoria, animalcules and microscopic plants, which, partly decomposed, partly continuing the floating vegetation, soon fill the basins and cover the bottom with a floating of clay-like mould. So rapid is the work of these minute beings, that in some cases from six to ten inches of this mud is deposited in one year. Some artificial basins in the large ornamental parks of Europe have to be cleaned of such muddy deposits of floating plants, mixed with small shells, every three or four years.

When left undisturbed this mud becomes gradually thick and solid; in some cases, of great thickness; affording a kind of soil for the growth of marsh plants, which root at the bottom of the basins or swamps and send up their stems and leaves to the surface of the water or above it; where their substance becomes in the sunshine hard and woody.

As these plants periodically decay, their remains of course drop to the bottom of the water; and each year the process is repeated, with a more or less marked variation in the species of the plants. After a time the basins become filled by these successive accumulations of years or even centuries, and then the top surface of the decayed matter, being exposed to atmospheric action, is transformed into humus and is gradually covered by other kinds of plants, making meadows and forests.

In this way many deposits of peat are buried under ground and remain unknown until discovered by diggings or borings. Such are the immense peat deposits in the great swamps of Virginia, the Dismal swamps, and all along the shores of the Atlantic from Norfolk to New Orleans.

In other cases when basins of stagnant water* are too deep for the vegetation of aquatic plants, nature attains the same result by a different special process, namely, by the prolonged vegetation of certain kinds of floating mosses, especially the species known as *sphagna*. These floating masses grow with prodigious speed, and expanding their branches in every direction over the surface of ponds or small lakes, soon cover it entirely. They thus form a thin floating carpet, which as it gradually increases in thickness serves as a solid soil for another kind of vegetation, that of the rushes, the sedges, and some kinds of grasses, which grow abundantly mixed with the mosses, which by their water-absorbing structure furnish a persistent humidity sufficient for the preservation of their remains against aërial decay. The floating carpet of moss becomes still more solid, and is then overspread by many species of larger swamp plants, and small arborescent shrubs, especially those of the heath family; and so, in the lapse of years by the continual vegetation of the mosses, which is never interrupted, and by the yearly deposits of plant remains, the carpet at last becomes strong enough to support trees, and is changed into a *floating forest*, until, becoming too heavy, it either breaks and sinks suddenly to the bottom of the basin, or is slowly and gradually lowered into it and covered with water.

That the breaking down of the surface vegetation of lakes is not a fanciful but a real explanation of the deep peat deposits of Denmark, is proved by a remarkable adventure of the people of the Jura mountains in Switzerland, where a peat-bog forest once sank suddenly, and now lies at the bottom of a lake over which a fresh carpet of peat has since then grown. Lac d'Etaillères, six or seven miles from Fleurier in the Val des Ponts, is a piece of open water in one of the extensive series of peat-bogs stretching along the parallel valley of the Brèvine, where I spent many days and nights studying the various phenomena of the for-

*This word should not be understood as water absolutely destitute of all movement, either by access or egress; but merely water not exposed to sweeping currents or great change of level. No peat can grow where the bottom of the basin is occasionally dry and exposed to the action of the atmosphere.

mation and growth of the peat. Previous to the year 1500, A. D. a forest occupied the site of the present lake and covered the flat floor of the valley. There is a legend that, one evening in that year, the people of the neighboring farms saw their cattle come galloping with tails erect out of the forest homewards, as if in a great fright, while the air was filled with a noise of the tumultuous crashing of trees. By morning the forest had disappeared and in its place lay two beautiful small lakes. The lakes are there still, and when the weather is clear one may see the trees lying prostrate at the bottom of the water; but sphagna and other kinds of floating mosses are growing around the banks and spreading over the surface of the lakes, which have already become partly covered with their carpet.

The operation is nevertheless not yet complete, at least not always; for, after the sinking of the first floating carpet, the vegetation of the mosses may begin again at the clear surface of the water, and, in the course of years or centuries—no matter how many, for nature is never in a hurry—a new carpet covers the basin, another cycle of vegetation begins and continues its course, until this second mass of vegetation, like the first, is pressed down under water.

Thus we have two superposed beds of vegetable remains in process of slow decomposition, or subjected to the beginning of the transformation into coal. And both the layers are composed in the same way, the lower part being a mass of the remains of small vegetation, mosses, water plants, etc., the upper part covered with trees; that is, two beds of peat and two forests.

This exposition has no hypothetical character whatever; it is merely a description of observed facts. In the southern part of the United States the results of the process are differently exhibited. The bottom of Drummond Lake, of the Dismal Swamp, for example, is formed of a forest, once growing at the surface, but now prostrate and buried beneath 15 or 20 feet of water. Beneath it probably lies a deposit of the detritus of plants, or a bed of peat; while the moss vegetation is now advancing into the lake from all

around its edge; so that it is not possible to reach the open water without sinking deeply at every step into the floating carpet.

In New Jersey, near the sea shore, very large tree trunks are dug out from beneath a covering matter, muddy peat, from 10 to 20 feet thick.

Around New Orleans borings for water have traversed, at various depths, a succession of beds of peat and forest, separated by deposits of sand.

In northern counties where a colder climate is particularly favorable to the growth of the mosses, the process is still more plainly exhibited, either as a work completed in the past, or still actively carried on and open to observation of the present generation.

During a protracted tour of exploration of the peat deposits of Northern Europe, in 1845, I made important observations on the peat bogs, and I cannot do better than translate from my records, published in the Revue Suisse, an account of the disposition of the materials composing a bed of peat which, when I visited it in Denmark, was regularly mined for its fuel, the basin being drained by hydraulic machines.

In Sweden and Denmark peat deposits, rarely of wide extent, but sometimes very deep, are of frequent occurrence. The soil is undulating and diversified with a great number of large ponds, or small lakes, which have been filled by a growth of peat as described above.

Between Hirsholm and Waldmarsland, along a direct line of 9 miles, I examined forty peat-bogs, isolated, or connected by runlets of water. At Waldmarsland, near Copenhagen, I had the opportunity of examining the separate layers and the composition of one of these peat deposits; which in that country are considered mines of wood.

At the bottom, that is at the lowest level reached by the drainage, lay 4 feet of black compact peat; and over it a stratum of prostrated trees (*pines*,) most of them laid in the direction of the slope of the basin, the tops of the trees pointing toward the center. The trunks of a large number of these trees measured from 6 to 10 inches in diameter.

They still kept their branches, embedded in a mass of leaves and cones, and even mushrooms. According to the proprietor of the mine, this lower stratum of peat and prostrated forest had a total thickness of 8 feet.

It was overlaid by a bed of black peat 4 feet thick, covered in its turn, like the other, by a bed of prostrated trees (*birches*, Betula alba) 3 feet thick.

Above that again was a third bed of peat, 6 feet thick, less compact than the two beneath it, and of a yellowish color, but covered in the same manner by a stratum of large trunks of *oaks*, some of them 2 and 3 feet in diameter, their wood being still in so perfectly sound a state of preservation that they could be cut and sawed for timber.

Over the oaks there was a fourth bed of fibrous yellow peat, 3 feet 8 inches thick, made up mostly of mosses not yet fully decomposed.

The total thickness of these deposits, so far as mining operations exposed it, was 30 feet; but the proprietor, one of the best informed land owners of the country, informed me that both his own deposit and others in that region were known to be at least twice as deep, but were never worked to the very bottom on account of the difficulty and cost of draining them.

In going from Malino to Lund, I wished to know positively if, as it had been many times asserted, there was any real danger in trying to cross one of those peat-bogs still in process of growth. Cautiously advancing over a perfectly horizontal plain covered with mosses I was not more than twenty paces from its border when the soil seemed at once to divide under my feet, and beginning to sink into it far more rapidly than I thought safe, I laid myself down and was helped out of the situation by my guide's whip, which he extended to me. Everywhere in Denmark and Sweden, especially in Scania, they relate thrilling tales of fatal accidents upon the swamps. There are numerous popular legends of the disappearance of people who, through carelessness, or wandering, lost in the night, have entered these deceptive bogs and never been seen again. It is even as-

serted that in old times criminals were condemned to cross them as a death penalty.

However this may be, the peat bogs of those countries are full of remains of various kinds: skeletons of men, and of many species of animals, especially of mammalia, and even of the aurochs; and relics of ancient unknown races of men, implements of stone, of copper and of iron. The museums of Copenhagen, Lund, and Stockholm contain a prodigious quantity of these remains.

The water necessary for the growth of the plants which compose peat, and for the preservation of the vegetable remains against rapid decomposition, is not always in the shape of standing water, ponds or lakes. An ordinary spring of water will answer the purpose. Or, as has been said above, the moisture of the air may suffice. In the first case the operation depends upon the nature of a special kind of moss, called *sphagnum*, already mentioned, which has a very peculiar conformation and in reality is not a true moss, but constitutes a separate family of plants not properly related to any other kind. From the seeds, when developed in water, the stems expand loosely in every direction, in floating tufts, which grow continually wider and thicker until the basin is entirely filled by their vegetation.

In the other case, upon land surfaces, where but little water is at hand for their original development, they grow in compact tufts (the stems not thicker than coarse thread) compressed upon each other; their branches and leaves being endowed with the peculiar property of absorbing moisture by their outer tissue and imbibing it like a sponge. In this way they obtain sufficient moisture to sustain their growth. But under certain circumstances, when the atmosphere, itself containing less moisture than the mosses hold in their tissue, they have the faculty of absorbing water by their stems and leaves from below, taking it up to the surface of their leaves, where it is evaporated into the atmosphere.

The growth of these mosses is not limited to seasons. Although its activity in freezing weather stops for a time,

it is resumed as soon as the temperature rises above 32°; and, as these mosses are constantly filled with water in such a degree that it can be squeezed from a tuft as it can be squeezed from a soaked sponge, they furnish the best kind of ground for the germination and growth of a large number of aquatic and other plants; which in fact germinate in these humected tufts of moss quite as well as they could do upon wet ground. These mosses, therefore, covering as they often do very wide areas, play the same part upon land surfaces as they do upon the water basins over which they float; the only difference being that on land surfaces their substance is far more compact.

Each year the peat bogs on land grow higher and higher, not merely by the yearly additions to the surface of the moss of sphagnum (and other plants mixed with it) but also by the added bulk of whatever woody remains get buried beneath the growth of moss. For, as soon as the moss bogs have become sufficiently compact, certain kinds of trees, like the tamarack, the bolled cypress and the birch in North America, and the smaller species of pines in Europe, are apt to invade their surfaces. The roots of these trees become covered by the mosses, which build up their high tufts around them, protecting from the decomposing action of the atmosphere not only the roots of the growing trees, but all such leaves, branches, pieces of bark, cones, etc. as may fall upon the moss covered surface.

When the atmosphere is very humid, or where the supply of water is furnished by some rivulet traversing the swampy plain, the peat grows upward rapidly and to a great thickness. In the great peat bogs of Les Ponts, Jura, (where I directed for a time the operations of the systematic extraction of the peat, for the Government of Neuchatel, in a way of promoting reproduction of the materials in the ditches) the thickness of the peat is found to vary between 8 and 30 feet. In some provinces of Russia the growth of peat is officially reported to be 50 and even 100 feet thick. In mountainous foggy regions like Ireland, Scania, and parts of Germany, the absorbant ability of sphagnum makes peat bogs grow even upon steep slopes,

which become for this reason more or less impassable. The mountain sides near the summit of the Brocken (the highest of the Hartz mountains) are sheeted with large bowlders of rock, covered over and filled in between with moss, which thus makes a continuous carpet.

The absorbing power of the peat mosses enables them to grow higher and higher above their original water level, from which they thus gradually emerge. The name *emerged bogs* has been therefore given to them.

The peat of emerged bogs is less compact; the annual layers are more distinct, generally well defined in their succession. At the top of the bog the layers measure about one inch in thickness; at the bottom less than ⅛ inch; and in old bogs still less. The growth, therefore, though not very rapid, is easily observed and registered, in several ways.

It may be measured by compass and level from the border of the swamp; the central portion of which becomes gradually higher and higher, screening from the view of a spectator on one side of it objects which had been before observable on the other side of it.

It may be estimated also by a time scale, in cases where ancient bridges, pavements, etc. whose epoch of construction is certified by documents, are discovered buried under beds of peat of known thickness.

Again, in places where peat-bogs have been worked for a number of years, old pits are encountered, now entirely refilled; and when this happens with peat, during the life of the proprietor who has himself dug the old pits and can recall the exact date, very precise data is thus furnished for learning the amount of time necessary for the reproduction of a given thickness of peat.

The rate of growth depends of course on atmospheric or other local circumstances, but, putting together many such pieces of documentary testimony obtained in different countries, the average production of compact matter may in a general way be estimated at 1 foot in a century.

In *immerged bogs*, formed of vegetable debris falling into water, the peat grows more slowly and less regularly. The

actual rate of its growth has not yet been positively recorded. In very extensive bogs, stretching between Swiss lakes, timber posts have been discovered on the line of an old road, and parts of a bridge buried beneath 5 or 6 feet of compact black peat. Although the exact date of these constructions has not been fixed, the discovery of Roman medals in the vicinity suggests the beginning of the Christian era. This shows that the kind of peat which results from the maceration of plants under water is of much slower growth than the peat layers of the *emerged bogs.* It is also more compact, and is quite black, the vegetable matter being more completely decomposed, and its internal structure generally so destroyed as to be unrecognizable. The peat of *emerged bogs* on the contrary is yellowish brown; fibrous; its annual layers distinct, and the woody fragments more generally recognizable.

This difference in the two kinds of peat has a direct bearing on the difference between bituminous and cannel coal, and furnishes grounds for supposing that the latter with its more compact texture and its destitution of any trace of any horizontal annual layers, and of vegetable remains, has been produced by plant growth under water, and decomposed under water, like submerged peat. Bituminous coal on the other hand with its distinct stratification, has been produced by the accumulation of vegetable materials above water; and preserved against rapid decomposition by the great humidity of the atmosphere. That the earth's atmosphere was thoroughly saturated by vapors in the Carboniferous period is fully evidenced by the character of the flora of that epoch, marked by a prodigious abundance of Ferns and especially Lycopodiacæ. The great thickness of the carboniferous vegetable deposits is in accordance with the probable fact of an excessively humid atmosphere; for it is well established that all the deposits of *immersed peat* are generally thin. The thickest I have seen in the lacustrine peat formations of Switzerland, Denmark and Holland vary from 2 to 8 feet. The beds of cannel coal, which are the ancient representatives of such lake bogs,

are usually thinner than those of bituminous coal.* I do not know of any in Kentucky which are thicker than 4 feet. Some beds are, in places, cannel 3 to 4 feet thick, and, in places, bituminous 5 to 6 feet thick.

Thus far, we have been considering: 1, the growth of the peat by a continuous accumulation of remains of plants growing in place; 2, the mode of procedure of nature in performing the work; and, 3, the preservation of the woody matter against decomposition either by the water in which the plants are completely immersed, or by moisture which certain species of mosses absorb from underlying water or from the overlying saturated atmosphere. All these considerations tend to explain by analogy the accumulation of woody materials in the coal measures.

Now, to make the analogy more complete and more evident, we will examine some of the peculiar circumstances which accompany the formation of peat.

Peat bogs in the low countries are more extensively formed along the sea shore, especially near the mouths of large rivers, like the Somme, in France; the Weser and Elbe, in Germany; along the shores of the North Sea in Holland, and of the Baltic in North Germany, Mecklenberg, Pomerania, Denmark, Sweden, etc. Peat is formed everywhere where an expanse of water has become enclosed as a water basin sheltered from the invasion of the sea by bands of sand thrown up by the waves; or along the river valleys, by the natural levees which border most great rivers in some parts of their course, especially near their mouths. These natural dams are made by the deposit of muddy matter in times of inundation; since currents make their precipitations along their border lines, where the force ceases to be active, and at a greater or less distance from the maximum line of flow and parallel to it.

Behind such natural dams or levees, wherever the inundations do not overleap them, there remain shallow

---

*The anthracite coal of Pennsylvania is bituminous in its origin, at least most generally so. I have rarely seen it so compact that the horizontal layers were totally absent. The thick cannel coal deposits in Western Pennsylvania are very local.

basins with impermeable bottoms of soft mud or clay. These are invaded by vegetation and transformed into peat bogs. Along the shores of the sea also the waves and winds create long sand-dunes, some of which are very high. Behind these barriers, small creeks and even rivers are arrested in their flow, their waters expanding into shallow basins, which are invaded by plants and filled with peat deposits. These still retreats of vegetation are not always safe from disturbance; although sheltered for a time against the rivers or the ocean, it will happen that some extraordinary freshet, some extraordinary high tide, some tremendous storm, breaks down or through the barriers, and then the peat bogs become covered with a deposit of mud or sand.

Such events have been repeated at longer or shorter intervals, and still recur, and the results are clearly recorded in the constitution of peat bogs, some of which show the interposed layers of sand and mud which interrupted their regular growth.

I have already remarked that the great peat bogs which stretch between some of the lakes of Switzerland are divided in the middle of their thickness by a bed of sand and gravel, 6 to 9 inches thick, having 4 feet of peat above and as much underneath.

In the Departement du Nord in France, a large number of ditches have been cut for the working out of the peat, and some of the sections have been carefully recorded. In a book written by a French engineer, M. H. Debray,* may be found a number of sections from 15 different localities, the average of which is as follows:

	Feet.	Inches.
Boggy humus,		8
Gray marine sand or clay with marine shells,	3	0
Blue marine clay with marine shells,	3	0
First peat bed,	4	0
Sand with Cardium and Lutrariæ,		5
Second peat bed, rarely present,	very thin.	

*Guide geologique et archœologique de queleques tourbiéres du littoral Flamand et du Department de la Somme par M. Henry Debray conducteur du Ponts and Schaûmes, 1873.

Among the shells founed in the marine sand and blue clay, the author mentions *Cardium edule* (the common cockle shell,) and *Lutraria compressa* (both very abundant;) *Littorina rudis*, *Buccinum undatum*, *Pholas candida* and *Tellina balthica;* but, in the peat itself no marine shells have been found, and river shells very rarely.

One of the sections shows some difference in the composition of the material. The upper part, under the bed of humus, is composed of *four layers of sand*, measuring in all 5 feet; then a thin layer of earthy clay, overlying 5 feet of peat essentially composed of trunks, branches and leaves; then a layer of blue sandy clay 8 inches thick; beneath which lies a lower bed of peat 15 inches thick. In digging down to the last peat bed a strong smell of gas noisily escaped for nearly 5 minutes; and great bubbles of gas were formed at the surface of the water, which on breaking gave a strong smell of carburetted hydrogen.* In these deposits the upper surface of the peat bed is from 2 to 3½ feet lower than the mean level of the sea (See Recherches, &c., pp. 205, 206.)

In the lower parts of peat-bogs and sometimes underneath the peat, a vast number of implements, broken pottery, coins, &c., have been found, together with bones of animals, birds and fishes. Some of the earthenware vases seem to be of the best Roman type; other fragments of pottery recall ages of barbarism by their poor conformation and the disproportion of their parts, and were probably manufactured by the ancient Gauls.

The same author mentions, as a remarkable fact, that the peat deposits must have been formed before an irruption of the sea; for, the marine clay which is superposed upon

*The proportion of hydro-carbon and bitumen in coal is about the same in peat, equaling the resinous, waxy and bituminous parts recognized by chemical analysis. In the chapter on Chemistry of the Peat I have recorded in my Researches on the Peat-bogs, some analyses of the material: one of these, by Klaproth, makes the

Solid products (pure carbon), ...	20 %
Liquid products (empyrcumatic oil,)	30 %
Gas (oxide of carbon or carburetted hydrogen, ...	12 %

Another analysis, by Ziegman, of very impure peat, gives 6.2% wax, 0.4% resin, 9.0% bitumen.

the peat is nowhere mixed with the upper layers of peat. This fact may show how and why the superposition of sandstone upon coal is always abrupt; and why there is never any intermixture of sandy matter with the coal. Wherever the growth of a peat bog has been stopped by dryness or any other cause, the upper surface of the peat is *crusted*, hardened, and transformed into a thin coating, quite impervious to the entrance of any kind of foreign matter; and it is upon this hard upper crust that the boggy humus forms; or, whenever the land becomes re-submerged, a new peat vegetation begins. In which case such a crust remains as a *parting layer* between two beds of peat, like the well-known clay partings between two coal-benches.

In the valley of the Somme, a river in Northern France, peat bogs have been long and extensively worked and show a certain definite resemblance to the structure of the coal measures; as the following section of one of the peat bogs will make plain:—

	Feet.	Inches.
Top humus,	0	8
Muddy clay with fresh water shells and silex,	5	0
Concretionary limestone and shells,	3	10
15 layers of peat of divers quality,	23	4

In this section, the peat deposit is continuous, with a variation in quality evidently due to a succession of different kinds of vegetation, and perhaps to a variation in the degree of prevailing humidity.

In the following section the peat is separated into layers by foreign matter:

	Feet.	Inches.
Calcareous sand, gray,	0	8
Black zone,	0	2
Peat in thin plates, (laminated,)	1	4
Argillaceous black peat,	1	0
Calcareous concretions full of shells,	0	6
Black argillaceous matter,	0	8
Grayish clay with plenty of shells,	0	8
Argillaceous peat,		thin
Calcareous concretions,		—
Laminated peat with trunks of trees and leaves,	10	0

In this section we have representatives of the calcareous concretions, and clay layers of a coal bed.

But the phenomenon is observed on a higher scale in Holland, along the sea shores, where peat is worked by shafts. One shaft was sunk through 15 feet of clay to the first bed of peat. Between the first and second bed of peat lay 14 feet of white clay. The second peat was 18 feet thick; and beneath it lay 10 feet of hard clay.*

Is there nothing in these sections to give us the solution of some of the more important problems of the constitution of the coal measures? The thin layers of clay which are interposed between peat deposits have their analogy in the clay partings of the coal. The heavy deposits of sand mixed with numerous marine shells, and the calcareous concretions, are also on a small scale comparable to the beds of sandstone, and limestone, &c., which make up the alternate strata of the coal measures between the beds of coal. And in the developement of gas from old peat deposits we find an explanation of the rock oil and gas deposits of the coal measures and the formations which underlie them.

If it was possible for me now to continue the description of the modification of the work of water peculiar to the formation of peat, most of the questions suggested by students of the coal strata would certainly be answered.

It must however be kept in mind that all the agencies which contributed to the formation of coal beds worked on a prodigiously larger scale than those which are now in activity for the formation of peat. Then, the deposits of vegetable remains were from an exceptionally exuberant vegetation, favored by the greatest possible humidity of the air, and a superabundance of carbonic acid in the atmosphere. It was a vegetation of which we can scarcely get an idea from anything now visible. Acrogenous plants, Ferns, Lycopods and Equisita (Horsetail) composed nearly the whole flora of the coal period. All the plants of those orders; represented by numerous genera, were then large trees, their trunks measuring from 1 to 3 feet in diameter, forty to 100 feet tall, or even more; growing close together, and forming an impenetrable thicket of stems, branches

*De Luc, lettres physiques and morales, p. 125.

and leaves; whereas, at the present day, the same kinds of plants are represented by mere herbage of small size, with stems and branches scarcely as thick as a goose quill, and only one or two feet high. Most of the land surface was then a vastness of swamps, in which the first growth, generally floating or creeping plants, was essentially composed of a peculiar species, the *Stigmaria*, whose immensely long stems and branches, from 4 to 6 inches thick, were woven together, like the thin, matted, floating stems of the *Sphagnum* of the present age, into an immense woven mat, or thick carpet, over which the luxuriant land vegetation of the coal soon spread itself. And, of course, we must suppose that such an accumulation of ponderous material, such a mass of vegetation, sank of its own weight at times and places into the water beneath and became wholly submerged. This supposition becomes a certainty in view of the superposition of thick beds of sandstone, shale, clay, ironstone and limestone upon the old beds of coal.

To account for the succession of coal beds separated from each other by many feet or yards of rock strata, and constituting a mass of coal measures several thousand feet in total thickness, it is necessary to take into consideration those very slow downward movements of large areas of the earth's surface which have taken place in all geological ages, and were nearly continuous on a grand scale during the whole time in which the numerous formations of Middle and Western Pennsylvania were being deposited; ending with the rise of the whole region to its present height at the end of the Coal Measure age. During all the last part of the downward movement the coal vegetation flourished magnificently, but was interrupted by inroads, of the sea on an equal grand scale; and these inroads which explain the intermediate sandstone, shale, limestone and iron ore beds, were precisely similar—but vastly greater and perhaps lasting for a much longer time—to those which have been described as happening in the history of the formation of the peat-bogs of our own day.*

*See also a recent Memoir on this part of the subject by E. Hull, Directer of the Geological Survey of Ireland.

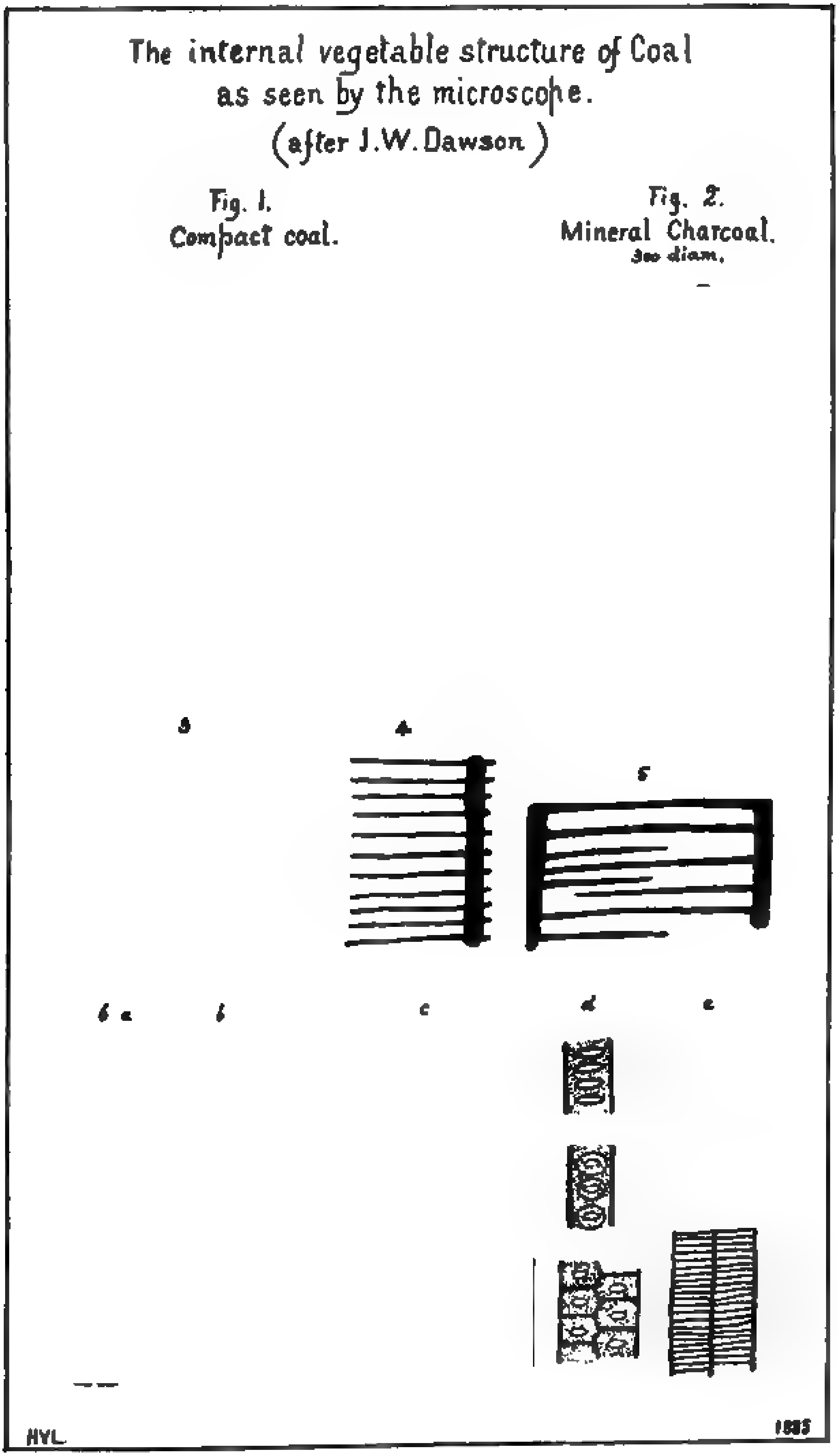
From all that has been said then it plainly appears that in the growth of peat we have a microcosmic but true representation of the formation of the ancient coal.

Notes by J. P. Lesley.

In the summary of the Second Geological Survey of Pennsylvania, which I am preparing, with the approbation of the Board of Commissioners, for the use of citizens of all parts of the State who find it difficult or tedious to consult the numerous and elaborate reports of the progress of the Survey in the several counties, I illustrate my description of the coal beds with pictures of what may be seen when slices of our coals, ground so thin as to become transparent, are placed under the microscope magnified to 50, 100 or 1,000 diameters.

Every body is acquainted with the fossil tree-stems which lie, mashed flat, between the layers of black slate which form the roof of our coal mines, and in the beds of solid sandstone which cover the roof-slates. Some may have had an opportunity of seeing a standing forest of tree stems, retaining their round form, but turned to stone (except their bark, which is usually turned to coal,) rooted in the roof shales and rising vertically through the overlying sand rocks or sandy shales. Stumps and tall stems, broken off above, occur in multitudes in all the coal fields of the world, and pictures of them, drawings of their scarred and channeled barks, and figures of the leaves, nuts and seeds which, falling from them while they lived into the mud, have been beautifully preserved in the roof shales of some coal beds, may be found in a hundred published geological books and memoirs.

The most recent and complete series of representations of the fossil barks, woody fiber, fern fronds, fruit, &c., found in the roof shales and coal-bed partings has been published by the Survey as Report of Progress P, Vols. I and II, (1880,) bound in one, with its Atlas of 85 plates, bound in a separate volume, and Vol. III, (1884,) carrying the number


The internal vegetable structure of Coal
as seen by the microscope.
(after J.W. Dawson)
Fig. 1.
Compact coal.
Fig. 2.
Mineral Charcoal.
300 diam.
HVL
1885

of plates up to 108. This great work embodies the results of the life-long observations of the venerable fossil botanist, Leo Lesquereux, now eighty years old, and still active in the science, who is recognized both in Europe and America as the discoverer of the true explanation of the origin of coal, based upon his first investigations into the mode of growth of peat bogs, as described by himself at my request in the foregoing paper.

Pictures of the internal vegetable constitution of the coal itself are not so accessible; because the soft tissues of coal plants growing in water were macerated into an almost undistinguishable mass of pulp, which makes the microscopic inspection of them very difficult. But, to show what can be seen in specimens properly prepared, I borrow one or two illustrations from Dr. now Sir James W. Dawson, principal of McGill College, Montreal, one of the most distinguished of living fossil botanists. His first elaborate treatise on the vegetable structure of coal was published, with 4 plates of figures, in the 15th, Vol. of the Journal of the London Geological Society in 1859; and his second treatise, with 8 plates of figures, in the 22nd Volume. in 1865. From plate 3 of the first treatise I take the magnified picture of the cell-structure of solid coal of Lingan, Nova Scotia, (Fig.1.); and a picture of the disc-bearing cell structure of a thin film of "mineral charcoal" from a Picton bed, magnified 300 diameters (Fig. 2.)

Dr. Dawson says in his memoir that compact coal exhibits now very little of its original cell structure, because the cells have been pressed together into an indistinguishable mass, and chemical changes have been going on for ages in the mass, producing segregations of bituminous matter which have sometimes been mistaken and figured for the original cells. Hutton appears to have seen the true cells. Goeppert figures them as obtained in the ash of coal. Dawson brought out the cell structure of lustrous compact coal by the use of nitric acid; and Fig. 1 represents them in a sufficiently perfect condition. Fig. 3 represents the gymnospermous bordered pores of Sigillaria (?) in the layers of mineral charcoal, magnified 1,000 diameters. Figs. 4 and

5 show the ladder-shaped woody tissue (scalariform vessels) of two kinds in mineral charcoal, magnified 300 diameters. Fig. 6 represents longitudinal sections from the axis of Sigillaria, 300 diameters ; and Fig. 6 a, a transverse section.

For the purpose of the present paper these few exhibitions of the vegetable origin of our coal beds will suffice ; and I have chosen those made nearly thirty years ago, first for the purpose of showing how long investigations into the origin of coal were successfully pursued, and secondly, because the conclusions arrived at then have been since verified and confirmed by the work of later investigators, especially by those who have discovered many coals crowded with the preserved pollen of the plants of the coal age. These will be given in my Summary Report.

Not often is Nature caught in the act of performance ; she behaves like a loving house-mother on Christmas eve, moving noiselessly about, that the children be not awakened, while she fills their stockings with toys and sugar plums. Sometimes a plank in the floor will creak, or a piece of match-wood snap ; that cannot always be helped. Volcanic action is impossible without periodical eruptions, nor a restoration of the elevation of worn-down highlands without occasional earthquakes. But most of Nature's operations are so noiseless, and so hooded from human eyesight, that Geology plays with her a perpetual game of blindman's buff, and is only now and then successful at a catch, as in the case of the Lac d'Etaillères, narrated by Mr. Lesquereux in the foregoing paper.

Preliminary Report of work done in 1885, on the re-survey of the Pittsburgh Coal-Region.

BY E. V. D'INVILLIERS.

CHAPTER I.

Introduction.

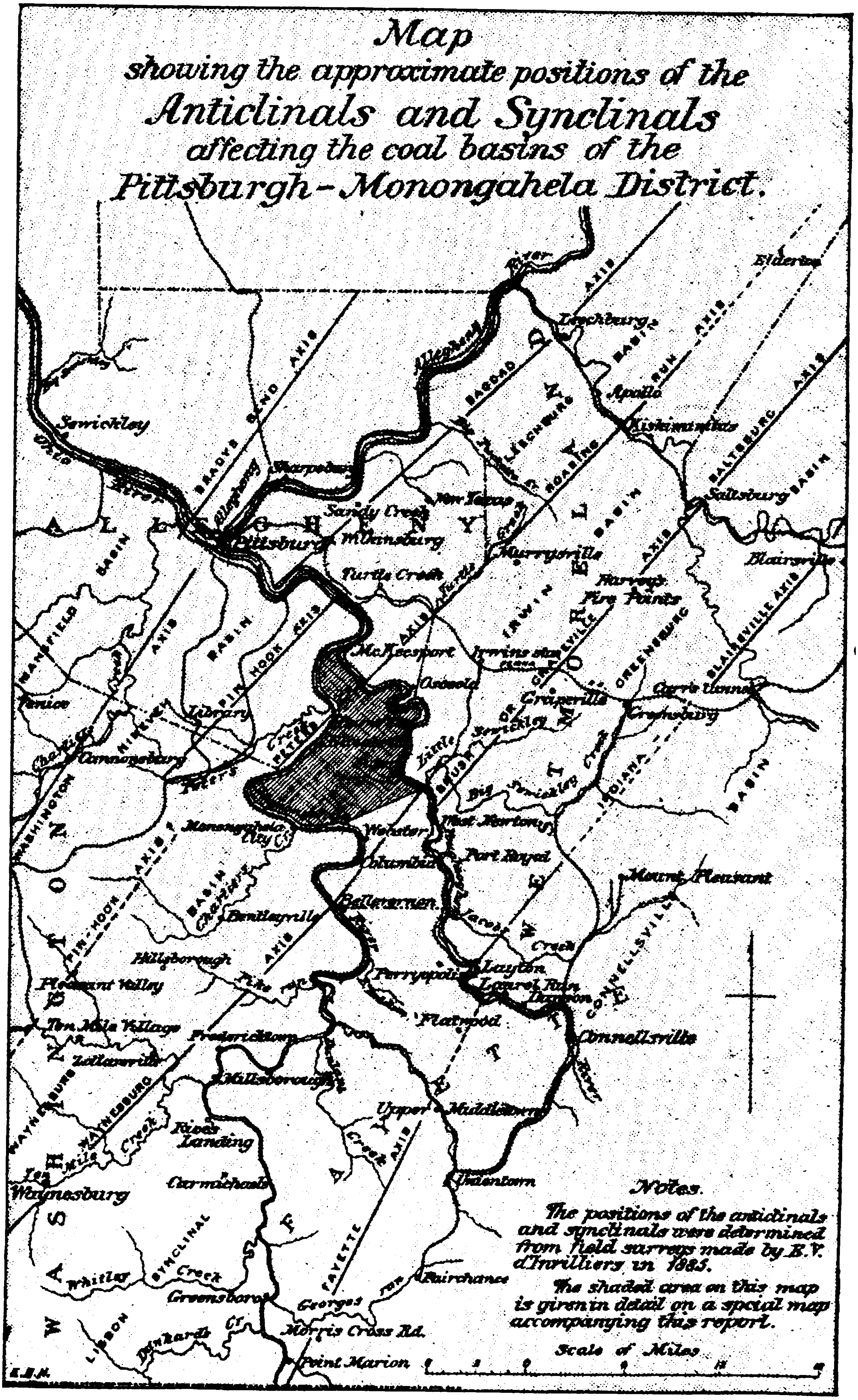
The Pittsburgh region has no clearly definable geographical limits; for, its principal coal-bed, on which are located most of its collieries, extends westward into Ohio, southward into Virginia, and north-eastward as far as Indiana county.* It is, however, fairly well represented by the area of the accompanying map (page 126).

During the last season the greater part of it was revisited; outcrops were located; new levels were taken and old levels rectified; and a large mass of materials was collected for a full report to be published after the field work of 1886 has been finished.

For this preliminary report, a typical portion of the region is selected for minute description, as a good illustration of the geology of the whole; and this portion is designated on the little map by cross-bars.

Another map of the selected portion has been constructed on a larger scale, and accompanies this report. This map

*The Pittsburgh region has an outspread of the Pittsburgh Coal-bed 50 miles long by 50 miles wide within the limits of the State. In the north-western part of this area the bed is 2′ or 3′ thick, increasing in thickness eastward and southward to 6′ of good coal at Pittsburgh, 10′ up the Monongahela, and 12′ up the Youghiogheny. What the thickness of the bed may be underneath the uplands of Washington and Greene counties we now know by the new gas-wells. It maintains its thickness in that direction. An average of 8′ for the whole region looks like a fair one. This gives 8,000,000 of tons to the square mile, and there are 2,500 square miles. Allowing one half of the area to be interval-separating outcrops, we have then 10,000,000,000 tons remaining in this one coal bed. Allowing 50 per cent. for pillars, bad mining, and waste of


Map
showing the approximate positions of the
Anticlinals and Synclinals
affecting the coal basins of the
Pittsburgh-Monongahela District.
Notes.
The positions of the anticlinals and synclinals were determined from field surveys made by E.V. d'Invilliers in 1885.
The shaded area on this map is given in detail on a special map accompanying this report.
Scale of Miles
Sewickley
Pittsburgh
Sandy Creek
Turtle Creek
McKeesport
Library
Monongahela City
Bentleyville
Hillsborough
Pleasant Valley
Ten Mile Village
Zollarsville
Fredericktown
Millsborough
Rices Landing
Carmichaels
Waynesburg
Greensboro
Morris Cross Rd.
Point Marion
Fairchance
Uniontown
Upper Middletown
Connellsville
Dawson
Laurel Run
Layton
Perryopolis
Belle Vernon
Webster
Port Royal
West Newton
Mount Pleasant
Greensburg
Irwins Station
Murrysville
Saltsburg
Blairsville
Kiskiminitas
Apollo
Leechburg
Elderton
Harveys
Five Points
Grapeville
Canonsburg
Venice
Flatwood
Brady's Bend Axis
Waynesburg Axis
Fayette Axis
Blairsville Axis
Saltsburg Axis
Greensburg Basin
Fayette Basin
Allegheny
Westmoreland
Washington
Greene
E.B.H.

embraces Lincoln, Elizabeth and Forward townships of Allegheny county; surrounded on three sides by the Monongahela and Youghiogheny rivers, along the valleys of which the Pittsburgh Coal-bed is mined for both a railroad and a river trade.

On the larger map the details of the outcrop line of the Pittsburgh Bed are shown; the levels above tide of the adits; and the underground anticlinal and synclinal structure. As the accuracy of this representation must greatly depend on the accuracy of the levels above tide assigned to the gangway mouths, it is proper to remark that considerable difficulties were at first encountered in securing a good railroad base line for barometric level work. Indeed after all corrections, I cannot guarantee the correctness of the Baltimore and Ohio Railroad elevations.

Many elevations were furnished me by resident mining engineers; but the datum level was often assumed, and had to be adjusted.

In this chapter will be found a list of all points of observation occupied by me during the field season (mostly along the outcrop of the Pittsburgh Coal-bed); with their elevations above tide; arranged by counties and townships, for use in future work; so that a correction of any errors may be obtained before the publication of my final report. Thus far they have satisfactorily indicated the geological structure of the field.

The usual stagnation of the coal business during the early summer months, with the succeeding labor troubles in the autumn of 1885, kept a large percentage of the mines closed until the New Year; so that only a limited number of mine

---

all kinds, we may set down its coal available for market in the future at 5,000,000,000 tons.

The output of the Monongahela slackwater in 1884 was double what it was ten years before. If it goes on doubling every ten years the output of the Pittsburgh bed will reach the rate of the British coal trade, say 200,000,000 in about forty years from now; and were the doubling of the rate to go on still, the bed would be exhausted in about eighty years from now. But such calculations are evidently ridiculous, especially in view of the growing competition of other coal-beds and other coal-regions of the United States. No rate of increase in the output of coal from the Pittsburgh bed will exhaust it in less time than many centuries; of this we may be perfectly sure.—J. P. L.

descriptions are presented in this report. During the spring of 1886 the Survey will be extended over the larger part of the Pittsburgh region (as embraced by the map, page 126), and I am assured of the hearty coöperation of persons whose interests are identified with its completion.

*Railroad and Miscellaneous Levels.**

The *Railway lines*, which traverse quite a large part of this territory, have furnished levels which served as a base for the various barometric observations taken in the region.

The following tables will show the elevations of railroad grade at the respective stations.

The succeeding tables show elevations of *Pittsburgh Coal-bed, etc.*, at various points visited.

1. Pennsylvania Railroad.†

(Table 1 of Report N.)

Stations.	Above high tide at Philadelphia.	Above mean level of Atlantic Ocean.	Distance from Pittsburgh.
	Feet.	*Feet.*	*Miles.*
Pittsburgh Union Depot, . .	738	745	
Lawrenceville, ...	773	780	2
Millvale, ...	826	833	3
Shadyside, ...	849	856	3½
Roups', ...	875	882	4
East Liberty, ...	911	918	4½
Torrens, ...	913	920	5
Homewood, ...	916	923	6
Brushton, ...	915	922	6½
Wilkinsburg, ...	916	923	7
Edgewood, ...	916	923	7½
Swissvale, ...	915	922	8

*These levels are all referred to Ocean level, and in the succeeding tables the various points occupied during the season are recorded, with the desire to have them verified for the final report. The arrangement by county and townships will facilitate examination, and all corrections or errors noted should be sent to E. V. d'Invilliers, 711 Walnut street, Philadelphia.

†Note.—The elevations at the various stations, on the Penn'a R. R., were copied from the engineer's notes, by permission of Mr. W. H. Wilson, its consulting engineer.

The datum, or base of levels, is ordinary high water in the Schuylkill River. This datum, according to Mr. James T. Gardener's determination, is 6.913 above mean surface of the Atlantic Ocean. *These 7 feet are added in the second column.* Decimal parts of a foot do not occur in these lists. When below .5 they have been omitted; when more than .5 a whole number has been substituted.

STATIONS.	Above high tide at Philadelphia.	Above mean level of Atlantic Ocean.	Distance from Pittsburgh.
Hawkins,	876	883	9
Copeland,	846	853	9½
Braddocks,	821	828	10
Brintons,	750	757	12
Oak Hill,	743	750	
Turtle Creek,	743	750	13
Springhill,	742	749	
Walls,	744	751	15
Stewarts,	784	791	17
Carpenters,	847	854	19
Larimers,	859	866	21
Irwins. *Youghiogheny R. R., (See Table 3,)*	877	884	22
Shafton,	898	905	23
Manor,	935	942	24
Penn,	967	974	26
Grapeville,	1052	1059	28
Radebaughs,	1143	1150	29
McGrann's tunnel (west face)	1156	1163	
Greensburg, *B. M., east face of Greensburg tunnel, on top of rough part of second course from bottom "R" 1079.52, 1086.52, ocean level. S. W. Penn'a R. R. junction, 3,300 feet east of tunnel elevation; 1,063 feet above high tide in the Schuylkill river, at Phila., and 1,070 feet above ocean level,*	1084	1091	31
Blairsville intersection, (see Table 16,) W. P. R. R.,	1106	1113	54

2. South-West Pennsylvania Railroad.

(Table 33 of Report N.)

	Above tide.	Ocean level.	Distance from Greensburg.
Greensburg,	1084	1091	
Greensburg Junction, *junction with P. R. R. near Greensburg; (see Table 1,)*	1063	1070	
East Greensburg,	1055	1062	1
Huffs.	994	1001	3
County Home,	972	979	
Fosterville,	960	967	5
Youngwood,	950	957	6
Jack's Run,	947	954	
Paintersville,	945	952	8
Sewickley Creek,	936	943	
Hunker's,	938	945	
Bethany,	1044	1051	
Tarr's,	1092	1099	13
Stoner's Summit,	1138	1145	

	Above tide.	Ocean level.	Distance from Greensburg
Hawk Eye,	1060	1067	
Scottdale,	1035	1042	18
Jacob's Creek,	1027	1034	
Everson,	1027	1034	
Valley Works,	1068	1075	19
Pennsville Summit,	1086	1093	
Pennsville,	1047	1054	20
Davidson,	891	898	
Connellsville,	908	915	25

The levels of the Southwest Pennsylvania R. R. were furnished by Mr. G. W. Leuffer, Engineer.

The datum, or base of levels, is ordinary high tide at Philadelphia.

2a. South-West Pennsylvania Railroad Extension.

(Table 159 of Report N.)

STATIONS.	Assumed elevation.	Above tide.	Above ocean.
Connellsville, *crosses Baltimore and Ohio Railroad, Pittsburgh Division here, on a Bridge, (see Table 4.)*	159.5	908	915
Subgrade Pier No. 1,	153.6	902	909
Ordinary water in *Youghiogheny river at Railroad bridge, South-west Pennsylvania Railroad,*	118	866	873
New Haven,	138	886	893
Wheelerville,	144	892	899
Dunbar,	246.4	995	1002
Ferguson,	376.2	1125	1132
Mt. Braddock, (deep cut; original surface 1,233.5,)	448	1196	1203
Lemont,	274.8	1023	1030
Hoggsett's Mill,	205.7	954	961
Uniontown, Main street and Broadway,	234.2	983	990

Levels on extension of Southwest Pennsylvania Railroad were furnished by Mr. John C. Oliphant, Engineer.

Datum is *high tide* in Schuylkil River, Philadelphia. Add 7′ for Ocean level. For the surveys an artificial datum was assumed, as shown in column 1. Column 2 gives this corrected for high tide at Philadelphia. Column 3 corrected for Ocean level.

This road crosses the Youghiogheny at Connellsville, and keeps up Dunbar Creek over to Uniontown, parallel with the Fayette Branch of the Baltimore and Ohio Railroad, Pittsburgh Division. (See Table 5.)

3. Youghiogheny Railroad.*

(Table 34 of Report N.)

	Above tide.	Ocean level.
	Feet.	Feet.
Irwin's Station, P. R. R., *junction with P. R. R. at Irwin's Station, (See Table 1.)*	877	884
Shaft No. 2,	986	993
Tunnel,	1104	1111
Chambers',	1075	1082
McGrew's,	974	981
Millgrove,	857	864
Little Sewickley, *first crossing Little Sewickley Creek*		
Marchands, *Youghiogheny Mine No. 1,*	783	790
Shaft No. 3, *elevation of coal 760'4 above tide,*	766	778
Youghiogheny, *Youghiogheny mine No. 2, elevation of coal 776'4 above tide,*	776	783
Sewickley Station, *mine No. 4, elevation of coal opening at this point, 800'4 above tide,*	773	780
R. R. Junction; *junction with B. & O. R. R., formerly, Pittsburgh and Connellsville R. R., (See Table 4.)*	761	768

4. Baltimore and Ohio Railroad—Pittsburgh Division.†

(Formerly Pittsburgh and Connellsville R. R.)

(Table 150 of Report N.)

STATIONS.	Assumed elevation.	Mean tide.	Ocean level.	Distance from Pittsburgh.
Pittsburgh, B. & O. R. R., Grant and Water streets depot,	237	751	735	
Birmingham Bridge,	237	751	735	
Soho,	255	769	753	2
Copper Works,	249	763	747	
Laughlin,	256	770	754	3
Frankstown,	269	783	767	4
Hazlewood,	275	789	773	
Grove,	270	784	768	
Brown,	243	757	741	
Salt Works,	252	766	750	6
City Farm,	247	761	745	9
Braddocks,	255	769	753	10

*The elevations on the Youghiogheny R. R. were copied from notes in the possession of Mr. John F. Wolf, engineer Penn'a Gas Coal Company, Westmoreland county. The datum is Penn'a R. R. at Irwin's Station.

†Considerable difficulty has been experienced in adjusting the levels of the B. & O. profile to agree with other railroads of the district. The elevations, as given in Report N, Table 150, are manifestly wrong. The following foot-note accompanies that table:

"Levels on B. & O. R. R., Pittsburgh Division, were copied from the profile in the office of the company, at Connellsville, Fayette county, Pa. The table

STATIONS.	Assumed elevation.	Mean tide.	Ocean level.	Distance from Pittsburgh.
Port Perry Junction,	251	765	749	11
Saltsburg,	251	765	749	12
Riverton,	251	765	749	14
McKeesport,	251	765	749	15
Long Run,	251	765	749	17
Ellrod,	254	768	752	18
Osceola,	254	768	752	20
Alpsville,	254	768	752	21
Coultersville,	254	768	752	22
Robbins,	254	768	752	23
Guffey,	254	768	752	24
Shaner,	254	768	752	25
Buena Vista,	. .		. .	26
Armstrong,	265	779	763	27
Scott Haven,	. . . .	. . . .	. .	28
Suter,	. . . .	. . . .	. . .	29
Sewickley, *Youghiogheny R. R., branch of P. R. R.,*	265	779	763	30
West Newton,	268	782	766	33
Snyders,	274	788	772	35
Port Royal,	278	792	776	37
Smithton,	278	792	776	39
Jacobs Creek,	283	797	781	40
Bannings,	290	804	787	41
Layton,	304	818	802	45
Oakdale,	335	849	833	49
Laurel Run,	342	856	840	
Dawson, *Hickman Run Branch R. R.,*	350	864	848	52
Sedgwick,	354	868	852	
Broad Ford, junction *Mount Pleasant Branch,*	359	873	857	55
Connellsville, *S. W. Penn'a R. R.,* (*See Table 2,*)	380	894	878	57

of levels (as formerly published), on the B.& O.R.R., Pittsburgh Div., was corrected by Mr. J. K. Taggart, assistant engineer. Datum, as noted on the profile, is *200′ below low water at Pittsburgh,* and *514′ above mean tide;* therefore, 514′ has been added to each elevation, as copied from profile, to get mean tide Baltimore=? ocean level."

Mr. Carll (Report I, p. 331) had a series of check levels run in Pittsburgh, whereby the track of the B. & O. R. R. depot was found to be 10.16′ lower than Union Depot, B. M. This would practically make the B. & O. track at Pittsburgh 735′, or 16′ lower than the figures in column 2, of Table 150, Report N. The first column gives Pittsburgh as 37′ above low water.

Low water=699.20 (Gardener.) This correction makes Pittsburgh 736.20, or but little different from calculation derived from Union Depot, B. M., or 735′.

The latter datum (735′) has been accepted by Mr. J. L. Randolph, consulting engineer B. & O. R. R., by letter of December 16, so that *16′ has been subtracted from all elevations of second column of Table 150, Report N,* to reduce to Ocean level. Even as at present adjusted, these levels are not very satisfactory, and the company seem to have very little appreciation of their real value.

5. Fayette Branch P. & C. Railroad.

(Pittsburgh Division B. & O. R. R.)

(Table 156 of Report N.)

Stations.	Mean tide.	Ocean level.	Distance from Connellsville
Connellsville,	894	878	
White Rock. *junction with B. & O. R. R. just above Connellsville,*	907	891	1
Fayette,	921	905	2
Watts,	991	975	3
Dunbar,	1011	995	4
Ferguson,	1138	1122	
Mt. Braddock,	1175	1159	7
Summit,	1211	1195	
Lemonts,	1084	1068	12
Evans,	1009	993	
Hoggsett's,	978	962	
Uniontown,	981	965	14

Levels on this branch were copied from a profile in the office of the company, in Connellsville, Pa., through the kindness of Mr. W. H. Taylor, Resident Engineer.

Datum—Mean tide at Baltimore, Md.

This road runs south-west along the east foot of Chestnut Ridge, towards the Virginia State Line.

6 Mt. Pleasant Branch P. & C. Railroad.

(Table 157 of Report N.)

Stations.	Mean tide.	Ocean level.	Distance from Connellsville
Connellsville,	894	878	
Broad Ford, *junction with B. & O. R. R., Pittsburgh Division, 2.4 miles below Connellsville,*	873	857	2
Morgans.	944	928	3
Tinstman's,	1076	1060	5
Valley Coal Mine,	1035	1019	
S. W. Pa. R. R. Crossing,	1040	1024	
Fountain Mill,	1042	1026	7
West Overton,	1045	1029	8
Iron Bridge,	1051	1035	9
Stauffers,	1057	1041	11
Mt. Pleasant,	1086	1070	12
End of road,	1083	1067	

Data obtained as in Table 5. This road runs north-east along the west foot of Chestnut Ridge.

7. Pittsburgh, McKeesport and Youghiogheny Railroad.

(Branch of the Pittsburgh and Lake Erie R. R.)

STATIONS.	Ocean level.	Distance from Pittsburgh.
Pittsburgh, B. M.,	700	
9th street,		
22d "	727.7	
26th "		
30th "	727.7	
Williamsburg,	720.1	
Becks Run.	730 24	3½
Walton's Tipple, Hays,	730.24	5
Homestead,	755.5	7
City Farm,	759.0	7½
Rankin,	742.0	9
Braddock,	735.6	10
Bessemer,	739.2	10½
Port Perry,	734.0	11
Brown's Tipple,	740.0	
Saltsburg,	748.0	12½
Demmler,	742.45	13
Riverton,	747.60	14
McKeesport,	754.0	15
Lynch,	746.0	16
Sinn's, (Quarry Sidings,?)	742.51	
Boston,	742 51	19
Greenoak,	756.0	21½
Duncan,	756 75	
Dravo,	756.75	
Stringtown,	756.75	25
Buena Vista,	756.75	26½
S. Buena Vista,	756.75	
Scott Haven,	762.0	28
Atlantic Mines,	7620.	
Douglass,	762.0	29½
West Sewickley,		
West Newton,	768.43	33
Cedar Creek,	776.0	36½
Port Royal,	780.55	
Smithton,	780.55	39
Jacobs Creek,	785.0	40
Larimer,		
Bannings,	793.55	
Whittsett,	793.55	43
Fuller,		
Layton,	811.51	46
Layton Quarry,		
Round Bottom,	827.0	
Virgin Run,		
Oakdale,	841.5	
Dickerson Run,	853.54	54
Fort Hill Mines,	851.5	
Mayville,		
Broad Ford Junction,	873.0	56
B. & O. connection,	878.44	
New Haven,	804.456	58

Elevations on P., McK. & Y. R. R. were furnished by Mr. J. Wainwright, Chief Engineer, from a profile in the company's office at Pittsburgh. This

road is a branch of the P. & L. E. R. R., and runs from Pittsburgh, up the Youghiogheny river, to New Haven, opposite Connellsville. The elevations along this road have been carefully taken and revised, and are to be relied on before those of the B. & O. R. R. and divisions on opposite side of river.

Datum is low water in Allegheny River at Suspension Bridge, 699.20 (Gardener).

8. Monongahela Division of Pennsylvania Railroad.

(Formerly Pittsburgh, Virginia & Charleston R. R.)

STATIONS.	Above tide.	Above ocean.	Distance from Pittsburgh.
Pittsburgh, Union Depot, B. M.,	738	745	
Fourth avenue station,			.5
Panhandle Junction; *junction with Pittsburgh, Cincinnati & St. Louis R. R.*,	753	760	
Nineteenth street,	776	783	2.4
Ormsby,	747	754	3.8
Beck's Run,	753	760	4.3
Baldwin,	754	761	4.8
Lucas,	753	760	5.5
Hays,	746	753	6.1
Howard,	743	750	7.4
Homestead,	747	754	7.8
City Farm,	744	751	8.3
Munhall,	744	751	8.7
Harden,	742	749	9.1
Green Springs,	732	739	10.3
Kenney,	743	750	11
Thomson,	751	758	11.4
Oliver,	745	752	11.8
Germantown,	749	756	12.3
Cochran,	749	756	12.9
McKeesport,	730	737	15.1
Dravosburg,	734	741	15.7
Camden,	741	748	16.9
Lostock,	737	744	17.5
Coal Valley,	749	749	18.2
Wilson,	743	750	18 9
Peters Creek,	739	746	19.3
Blair,	744	751	20.1
Wylie,	745	752	20.6
East Elizabeth,	738	745	22.0
West "	734	741	22.4
Jones,	741	748	23.2
Walton,	744	751	23.8
Hilldale,	737	744	24.6
Shire Oaks,	737	744	26 1
Coal Bluff,	738	745	26.5
Huston Run,	742	749	27.5
Courtney,	747	754	28.3
Riverview,	742	749	29.3
New Eagle,	739	746	30.1
Monongahela City,	741	748	31.1
Black Diamond,	740	747	32.4
Baird,	748	755	34.1
Webster,	748	755	35.1
West Columbia,	761	768	36.3
Bamford,	750	757	37.3
Lock No. 4,	752	759	39.8

	Stations.	Above tide.	Above ocean.	Distance from Pittsburgh.
	McKean,	751	758	41.1
	Bellevernon,	754	761	42.3
	Allenport,	752	759	44.9
	Lucyville,	754.5	761.5	47.0
	Woods Run,	753	760.0	47.8
	Coal Centre,	757	764.0	49.7
	California,	754	761.0	50.2
	West Brownsville Junction,	766	773.0	53.3
	West Brownsville,	760	767.0	54.3
Redstone Branch.	Linn,	775	782.0	55.1
	Tippecanoe,	847.6	854.6	58.9
	Smock's,	866.2	873.2	60.9
	Wolf Run,	888.4	895.4	63.0
	Upper Middletown,	904	911.0	64.8
	Vance Mill Junction,	916	923.0	66.6
	Walker's,	945	952.0	69.2
	Redstone Junction, *S. W. Pa. R. R.,*	944	951.0	69.8
	Uniontown, (See Table 2 a.)	983	990	70.7

Levels on the P., V. & C. R. R. were copied from a profile in the office of the company, at Pittsburgh, by permission of Messrs. D. M. Watt and F. F. Robb, Superintendent and Engineer.

Datum—P. R. R. levels.

This road ascends the west bank of the Monongahela river (after crossing to near Birmingham on a bridge), from Pittsburgh to West Brownsville, 54.3 miles. From West Brownsville Junction, 53.3 miles, the *Redstone Branch R. R.* extends up the creek of that name, to Redstone Junction, on the *Southwest Pennsylvania Extension,* about one mile below Uniontown.

9. Monongahela River Slackwater.

Elevation of Water in Pools.

	Above ocean level.
Pittsburgh; *low water in the Allegheny River at the Suspension Bridge,*	699.20
Pool No. 1,	709.69
Pool No. 2,	717.87
Pool No. 3,	729.30
Pool No. 4,	738.19
Pool No. 5,	750.40
Pool No. 6,	763.00
Pool No. 7,	774.30

Elevations furnished by Mr. J. Wainwright.

Datum—Pittsburgh, B. M., 699.'20 above ocean level (Gardener).

10. Wheeling Division, B. & O. Railroad.

Stations.	Mean tide, Baltimore.	Above ocean level.	Distance from Pittsburgh.
	Feet.	*Feet.*	*Miles.*
Glenwood, *diverging point of the Pittsburgh and Wheeling Divisions, and 4.7 miles from Pittsburgh,*	776	760	4.7
Hope Church,	750	734	5
Watsontown,	787	771	11½
Reiley's,	925	909	13½
Miller's Grove,	1035	1019	14
White Hall,	1204	1188	16
Curry's,	976	960	18
Wilson's,	940	924	19
Cochran,	882	866	21
Gastonville,	911	895	24
Finleyville,	930	914	25
Anderson,	972	956	27
Crouches,	1004	988	28
Thomas,	1178	1162	30
Gilkeson,	1085	1069	32
Kerrs,	970	954	34
Wyland,	983	967	35
Zediker,	1022	1006	39
Brady Summit,	1168	1152	—
Washington,	1038	1022	43
Chartiers,	1180	1164	47
Coffee Crossing,	1095	1079	48
Taylorstown,	1043	1027	51
Clayville,	1120	1104	54
Vienna,	994	978	57
West Alexandria,	1177	1161	60
Valley Grove,	960	944	64
Point Mills, (Branch.)	890	874	65
Roney's Point, (Branch.)	820	804	66
Triadelphia, (Branch.)	725	709	67
Elm Grove,	680	664	70
Mt. De Chantel,	699	683	72
Wheeling,	645	629	75

The elevations of Wheeling Division, B. & O. R. R., were mainly furnished by Mr. James L. Randolph, Consulting Engineer, from a profile marked "J. K. Taggart, 3-14-78," in which Pittsburgh is shown 751′, A. M. T., and Cumberland 638′, A. M. T. These elevations, as recorded by Mr. Randolph, are given in column 1. In column 2 I have subtracted 16′, to reduce to ocean level and agree with column 3 of Table 4.

Glenwood is not given in Table 4, but from profile of P. & C. R. R., its corrected elevation, 760′, agrees closely.

11. Pittsburgh, Cincinnati and St. Louis Railroad.

(Table 180 of Report N.)

STATIONS.	Mean tide.	Ocean level.	Distance from Pittsburgh.
Pittsburgh, *Union Depot*, (See Table 1,) . .	738	745	
Birmingham, *south side of Ohio river*, . . .	759	766	1
Jones Ferry, ...	750	757	
Temperanceville, ...	760	767	
Sheridan, ...	839	846	4
Cork Run Tunnel Summit, ...	864	871	
Ingram, ...	864	871	5
Crafton, ...	872	879	
Idlewood, ...	840	847	
Bridge No. 3, Chartiers creek crossing, . . .	807	814	
Bridge No. 4, public road, ...	787	794	
Bridge No. 5, Campbell's Run, ...	764	771	
Mansfield, *junction with Chartiers R. R.*, (*See Table 12.*)	766	773	8
Walkers Mill, ...	826	833	11
Oakdale, ...	899	906	14
Noblestown, ...	919	926	15
Willow Grove, ...	979	986	
McDonalds, ...	972	979	18
Primrose, ...	1014	1021	
Midway, ...	1099	1106	21
Bulger, ...	1149	1156	23
Bulger Summit, ...	1155	1162	
Bridge No. 17, ...	1009	1016	
Burgettstown, ...	1004	1011	27
Dinsmore Summit, ...	1089	1096	
Dinsmore, ...	1052	1059	
Hanlon's, ...	935	942	32
Bridge No. 19, ...	863	870	
Paris Road, ...	828	835	
Pennsylvania State Line, ...	825	832	
Bridge No. 22.	818	825	
Collier's, *in Virginia*, ...	800	807	36
Halliday Cove, ...	714	721	39
Edington, $\frac{3}{8}$ *mile east of the Ohio river*,	697	704	41.4
Ohio River Bridge, *91' above low water in the Ohio River*,	712	719	
Steubenville. *Junction of C. & P. R. R., River Division, is not at Steubenville, but at Mingo Junction, three miles south. The junction of the two railroads is made by a siding on a heavy grade, and the main tracks differ at the junction, in elevation, by some 10', P., C. & St. L. railroad being higher.*			

* Levels of the P., C. & St. L. R. R. were copied from a profile in the office of the company, at Pittsburgh, Pa. The profile was furnished by Mr. S. M. Felton, Jr., General Superintendent, and corrected by Mr. M. J. Becker, Chief Engineer.

Datum—Penna. R. R. levels. Add 7' for Ocean levels in Column 2.

12. Chartiers Railroad.

(Table 181 of Report N.)

STATIONS.	Mean tide.	Ocean level.	Distance from Mansfield.
Mansfield. *junction with P., C. & St. L. R. R.,* (*See Table 11,*)	766	773	
Leasdale.	787	794	1
Woodville,	797	804	2
Bridgeville,	815	822	4
Boyces,	858	865	7
Hill's,	893	900	9
Greer's,	896	903	10
Van Emman's,	915	922	11
Morganza,	931	938	
Cannonsburg,	928	935	14
Houston's,	942	949	15
Johnston's,	964	971	
Ewing's Mills,	971	978	18
Cook's,	996	1003	20
Washington,	1024	1031	23

Elevations on Chartiers Branch R. R. were furnished by Mr. M. J. Becker, Chief Engineer P., C. & St. L. R. R., Columbus, Ohio.

Add 7′ to reduce to Ocean level.

13. Pittsburgh Levels.

(Table 163 of Report N.)

Elevations of points in the City of Pittsburgh, Pa.

BENCH MARKS.	City datum.	Ocean level.
Window sill of Monongahela Incline Plane, check house,	407.075	1106.275
On Belt-course of Union Depot, main entrance,	47.203	746.403
On east end door-sill of Point Breeze hotel, at intersection of Penn and Fifth avenue,	273.814	973.014
On belt-course of Muushall's distillery, corner Penn and Water street	28.198	727.398
On door-sill of postoffice,	51.554	750.754
On embankment of *lower* (old) reservoir, Bedford avenue,	165.854	865.044
On embankment of *upper* (old) reservoir, Bedford avenue,	401.674	1100.874
On flow-line of Highland avenue (new) reservoir,	365	1064.200
On flow-line of Herron Hill (new) reservoir,	560	1259.200
On flow-line of Brilliant Hill (new) reservoir,	235	934.200

Elevations at different points in the city of Pittsburgh, Pa., were furnished by Mr. William Martin, Assistant Engineer.

Datum—*Low water in the Allegheny river* at the Suspension Bridge, which according to Mr. James T. Gardener's determination, is 699.20′ above the mean surface of the Atlantic Ocean. See page 655, vol. I, Hayden's Geological Survey Report of 1873.

14. Pittsburgh Levels.

(See Report I2, p. 330.)

	Above B. M.		Above Ocean.
B. M. Union Depot,	.	Accepted elevation,	745.26
Allegheny Valley R. R. B. M.,	4.14	Below Union Depot, B. M.	741.12
West Penn. R. R., junction P., Ft. W. & C. R. R.,	6.51	Below Un'n Depot, B. M. (Carll)	738.75
East Lane crossing, W. P. R. R.,	3.58	Below Un'n Depot, B. M. (Carll)	741.68
East Lane crossing, W. P. R. R,	7.43	Above ocean by W. P. R. R. profile.	
East Lane crossing, W. P. R. R.,	1.32	Too high by W. P. R. R. profile.	
Sycamore St. crossing, W. P. R. R.,	3.86	Below Un'n Depot B. M. (Carll)	741.40
Sycamore St. crossing, W. P. R. R.,	7.43	Above ocean by W. P. R. R. profile.	
Sycamore St. crossing, W. P. R. R.,	1.60	Too high by W. P. R. R. profile,	
Connellsville (B. & O. depot,) B. M.,	10.16	Below Un'n Depot, B. M. (Carll)	735.10
	7.35	Above mid-tide Baltimore B. & O. profile.	
	0.10	Too low by B. & O. R. R. profile,	
Pittsburgh oil well on Boyd's Hill,	107.02	Above Union Depot B. M.,	852.28

The above levels were taken by Mr. John H. Carll, 1876-1877, for the purpose of rectifying the system of railroad and oil well levels throughout northwest Pennsylvania.

Datum—*Low water in Allegheny River at Suspension Bridge*, 699'.20, from which Union Depot, B. M., was determined=745'.26 above Ocean level.

15. Allegheny Valley Railroad.

(Table 164 of Report N; corrections in Report I2, p. 339.)

Stations.	Above Ocean. Profile elevt'n.	Above Ocean. Corrected. levels.	Miles from Pittsburgh.
Pittsburgh Union Depot,	745	745	
McCandless,	. . . .	740	3.4
Sharpsburg,	.	745	4.4
Brilliant,	747	747	6.0
Waring,	. . . .	747	6.6
Wildwood,	. . . .	747	7.7
Sandy Creek,	. . . .	746	8.8
Armstrong's,	. . . .	746	9.3
Iona,	. . . .	746	9.9
Verona,	745	746	10.3
Edgewater,	. . .	761	11.2
Hulton,	.	778	11.8
Johnson,	759	760	15.1
Logan's Ferry,	755	757	16.5
Parnassus,	762	763	17.4
Arnold,	792	793	19.0
Camp Ground,	.	789	
Tarentum,	777	778	20.7
Chartiers,	. . . .	765	22.2

Stations.	Above Ocean.		Miles from Pittsburgh.
	Profile eleva'n.	Corrected levels.	
Soda Works,	....	761	22.9
Graver's Ferry,	...	785	27.2
West Penn Junction; (*junction with W. P. R. R.*, (*See Table*,)	790	791	28.8
Kittanning,	809	810	44.5

The levels on the A. V. R. R. are the joint production of those obtained from the profile of the company, by permission of Mr. H. Blackstone, Chief Engineer, and from the results of Mr. J. H. Carll's surveys in 1877.

Datum—Penna. R. R., at Pittsburgh.

16. West Penn Railroad.

(Table 28 of Report N, and corrections in I2, p. 340.)

Stations.	Above Ocean.		Distance from Allegheny City.
	Profile elevt'n.	Corrected. levels.	
Pittsburgh Union Depot, B. M.,	.....	745.26	
Junction with P., Ft. W. & C. R. R., (See Table 14,)	....	738.75	
Allegheny City, East Lane, (See Table 14,)	743	742.00	
Bennett,	741	.....	2
Sharpsburg, *Main street*,	739	....	5
Ross,	745	.....	8
Fairview,	741		
Harmersville,	743	......	12
Springdale,	749	....	16
Bailey's Run,	753		
Tarentum,	757	.....	20
Natrona,	768	......	21
Karns,	768	......	23
Sligo,	775	.....	24
Butler Junction; *junction of Butler Branch*,	.....	769	27½
Freeport, (Depot,)	.....	772	28
A. V. R. R. Crossing, (See Table 15,)	785	791	29
Hill's Mills,	780		
Grinders,	827		
Townsend's Summit,	887	.....	37
Apollo,	823	......	39
Roaring Run,	830	......	42
North-west,	894		
Salina,	955	......	45
Helma,	1017		
Fairbanks Coal R. R. Connection,	933		
Grade near mines, } *Branch Line*,	1118		
Bottom of coal bed, } *Branch Line*,	1140	.....	
Saltsburg, *Market street*,	891	......	49
Livermore,	945	.....	58
Blairsville, *Market street station*,	1011	.....	63
Blairsville Intersection, *junction with P. R. R.*, (*See Table 1*,)	..	1113.00	66

Elevations in Allegheny County.*

City of Pittsburgh.

	Above tide.
Winebiddle estate, north of East Liberty; country pit, *Pittsburgh Coal*,	1089'
Irwin country pit, head of Forbes avenue,	1108
English pit, west of Nine-Mile Run,	1102
Fleming pit, Forward avenue,	1097
Cannon pit, north of Brown's Chapel,	1064
Country pit on east side of same outcrop,	1084
Brown's pit, above B. & O. R. R. track,	1040
Coleman pit, near Penn township line,	1150
Pittsburgh Coal at head of Wildwood avenue,	1120
Pit on Duquesne Heights, Little Saw Mill Run,	1011
Pit in 32d ward, on Southern avenue,	1011
Pit in 30th ward, river outcrop,	1031
Pit on branch of Saw Mill Run, Washington avenue,	1041
Pit at head of Incline Plane, 27th ward,	1021
Pit at head of 21st street incline,	1021
Pit at head of 29th street incline,	1031
Rear end of this pit in Lower St. Clair,	1021
Fox pit on plank road, (1035)	1023
Country pit, forks of Saw Mill Run, north-east of West Liberty,	991
Pittsburgh Coal at head of south-west fork, near St. Clair hotel,	981
Banksville pit, Union township, (955)	969

Penn township.

Billingstein and McKenzie pit, head of Nine-Mile Run,	1130
Elevation of Pittsburgh coal in Westinghouse well,	
F. Ellis' pit, head of Nine-Mile Run,	1148
Mason's country pit,	1148
Benjamin Elms',	1148
Eder's pit on Wynman's property,	1133
N. Y. & C. Co. Sandy Creek pit, entrance at trestle on same crop,	1128
Grade of Sandy Creek railroad in Sandy Creek village,	806
Graver's mine, Saltzburg road, north-east from Sandy Creek village,	1131
Country pit, Sandy Creek road, north of school house,	1081
John Stewart's pit, Saltzburg road,	1129
New York and Cleveland Gas Coal Company, No. 2, pit mouth,	1079
Water-pit at end of No. 2 tunnel,	1061
Pit on Pucketa road, Morrow's kiln,	1051

* Unless otherwise stated, in all cases where coal pits occur in the following ables, the *Pittsburgh Coal-bed* is referred to.

	Above tide.
C. Cunliff's pit,	1051
Johnson's pit, south-east corner of township,	1040'
Water pit of Plum Creek mines, N. Y. & C. G. Coal Co.,	1066
Plum Creek, main pit mouth,	1086
Gray's pit, east of Catholic church, *Plum township*,	1084
Miller's pit, *Plum township*,	1081

Chartiers township.

Pittsburgh Coal, above Sheridan station,	1100
Wettingill & Gormley's pit,	1068
Hodgson's pit,	1079
Summit of Crafton road,	1179
Craft's pit on east side of Crafton road,	1040
Phœnix pit, No. 1, on Chartiers railroad branch, Idlewood station,	972
Phœnix water pit, No. 2, on south-east side of hill,	959
Sterrett drift, north of cross roads,	976
Fox's new pit, north of Washington pike,	1010

Wilkins township.

Dickson's pit, east of Swissvale,	1112
McKelvey coal,	1097
Duquesne mine, main pit,	1092
Duquesne mine, entrance to third hill,	1081
Duquesne mine, entrance to fourth hill,	1075
Duquesne mine, rear pit to fourth hill, Muckle Rat Hollow,	1065
Hampton mine pit,	1097
Wyman & Sutton's country pit,	110)
Montgomery pit, in ravine south-west from Lime Hill school house,	1057
Oak Hill mine No. 3, Thompson's Run,	1015
Chalfant pit, (P. Kenyon), on Greensburg pike,	1010
Campbell's pit, Elliott's farm, north of Braddock,	1057
Corry pit, east from Hawkins station, P. R. R.,	1068
Country pit on hill north of Hawkins station, P. R. R.,	1073
Railroad beneath Oak Hill Colliery, No. 4, *Patton township*,	795
Oak Hill mine, No. 4,	1035
Pit opening on west outcrop, about 1 mile south-west of Oak Hill, No 4,	1041
Rear or south-east end of this tunnel, Patton township,	1025
South-east end of main tunnel, at Mrs. Clugstone's, Patton township,	1080
Pittsburgh Coal at school house, No. 1, in main tunnel, Patton township,	1062
Pittsburgh Coal, in ravine 1¼ miles north-east from Oak Hill, No. 4, Patton township,	1070
Country pit in ravine south-west from Monroeville, Northern turnpike,	1100

Above tide.

North Versailles township.

Pittsburgh Coal, Brown's Saltzburg mines, face adit, ... 970
Pittsburgh Coal, Brown's Saltzburg mines, butt adit, . . . 985
Pittsburgh Coal, east end of engine tunnel, ... 1026
Pittsburgh Coal, south tunnel, daylight at Ludwick's, ... 1071
Pittsburgh Coal, Tapley's country pit on Crooked Run, . 1076
Pittsburgh Coal, Brown's opening head of crop on Crooked Run, ... 1085
Pittsburgh Coal, Overholtz's country pit, south of Greensburg pike, ... 1136
Pittsburgh Coal, White's pit, north side of Greensburg pike, 1156
Pittsburgh Coal, Michaels' pit, on Greensburg pike, . . . 1186
Pittsburgh Coal, Wallace pit, north of Greensburg pike, . . 1181
Pittsburgh Coal, Miller's pit, north of Greensburg pike, . . 1196

South Versailles township.

Pittsburgh Coal, Foster pit near North Versailles line, . . 1124
Pittsburgh Coal, Powers pit, north of Reservoir Hill, McKeesport, ... 1068
Pittsburgh Coal, Mont Blanc coal, F. N. McClure, 1178
Pittsburgh Coal, John Christy pit, north of Youghiogheny river, ... 1123
Pittsburgh Coal, Dewees & Co. pit, north of Youghiogheny river, ... 1058
Pittsburgh Coal, Alpsville mine, pit mouth, ... 892
Pittsburgh Coal, Osceola mine, pit mouth, ... 955
Pittsburgh Coal, J. McClintock pit, east of Jack's Run, . . . 1148

Scott township.

Pittsburgh Coal, on George's Creek one-half mile from Chartiers Creek, ... 807
Pittsburgh Coal crop at George's Creek forks, ... 857
Nixon's drift on Chartiers Valley R. R., ... 826
Bain's drift on Chartiers Valley R. R., Leasdale station, . . . 832
Pittsburgh Coal crop, pit on Scrubgrass Run, ... 824
Pittsburgh Coal crop, pit south of Woodville, ... 823
Bower Hill coal pit, ... 844

Upper St. Clair township.

Coal pit on Chartiers Creek, near Scott township line, ... 817
Chartiers Block Coal Co. drift, on Panther Run, ... 876
Chartiers Block Coal Co. drift one half mile further up Panther Run, ... 887
Coal pit on Connor heirs' property, ... 887
Coal pit, McLaughlin's Run, D. Gilmore land, ... 802
Coal pit, McLaughlin's Run, W. Aber land, ... 817
Coal pit, McLaughlin Run, south of S. Collins, ... 832
Coal pit, forks of run, ... 868
Coal pit, W. Andrews, ... 868

	Above tide.
Baldwin township.	
Pittsburgh Coal (check house), Hays Beck Run mine, . . .	970
Pittsburgh Coal, entrance to first tunnel, Hays Beck Run mine,	978
Pittsburgh coal pit, rear end of Hays works, near Matthews' place, Saw Mill Run, ...	953
Pittsburgh Coal, Fairhaven bank, east fork of Saw Mill Run,	939
Pittsburgh Coal, McDonough pit, in ravine near Scott township line, . .	987
Pittsburgh Coal, country pit near crop below Castle Shannon,	952
Point View hotel, Brownsville road, ...	1224
Pittsburgh Coal, Cowan's pit, on Beaver Branch of Street's Run, ...	965
Pittsburgh Coal, pit at Grape Vine Inn, branch of Street's Run, ...	942
B. & O. R. R., (Wheeling Branch) at mouth of Beaver's Run, about	844
Reilly pit, north side of Street's Run, at this point, ...	
Mifflin township.	
Pittsburgh Coal, D. Calhoun country pit, east from Hays' Run, ...	1045
Pittsburgh Coal, R. Calhoun country pit, head of West's Creek, ...	1058
Pittsburgh Coal, G. Wesley country pit, head of branch to Whiteacre Run, ...	1040
Pittsburgh Coal, Bellwood mine, head of Whiteacre Run, .	1033
Pittsburgh Coal, Greensprings mine, (Fawcett & Co.,) head of incline plane, ...	1062
Pittsburgh Coal, Greensprings mine, south end of first tunnel, ...	1056
Pittsburgh Coal, Greensprings mine, south end of second tunnel, ...	1048
Pittsburgh coal, Greensprings mine, north end of third tunnel, ...	1038
Pittsburgh Coal, Cochran country pit on road, branch of Thompson's Run, ...	992
Pittsburgh Coal, country pit on road, rear of Colonel John Neel's workings, ...	968
Pittsburgh Coal, Neel & Oliver mine (abandoned) at Germantown, ...	956
Pittsburgh Coal opening, point of hill, Neel & Oliver workings, ...	956
Pittsburgh Coal old pit, Neel's lower coal works, (abandoned,)	946
Pittsburgh Coal Neel's third and largest opening, opposite McKeesport, ...	946
Pittsburgh Coal, Stone mine, head of incline, (Coal Valley mines,)	965

Above tide.

Pittsburgh Coal, Stone mine, entrance to second tunnel, branch of Thompson's Run, . . . 973

Pittsburgh Coal, Stone mine, rear of second tunnel, south side of Thompson's Run, . . . 985

Pittsburgh Coal, Stone mine, entrance to third hill, north-east of Union Church, Thompson's Run, . . . 1004

Pittsburgh Coal, Stone mine, entrance to third hill, ¾ mile west of Union Church, . . . 1005

Pittsburgh Coal, Stone mine, pit on public road, north of Gilday's B. S. S., . . . 1014

Pittsburgh Coal, Amity mine, (J. C. Risher & Co.,) pit in hollow, . . . 977

Morton Summit, north of Amity mine pit, . . . 1200

Pittsburgh Coal, Risher's, rear pit mouth, entrance to second hill, north side of Thompson's Run, . . . 1004

Pittsburgh Coal, Camden mine, head of river incline, . . . 943

Pittsburgh Coal, Camden mine, pit in ravine east of Lebanon Church, . . . 1037

Pittsburgh Coal, Alequippa mine, head of incline on river, 921?

Pittsburgh Coal, Alequippa mine, rear of post tunnel, . 938

Pittsburgh Coal, Alequippa mine, entrance to second hill, 910

Pittsburgh Coal, (Snodgrass) Rock Run mine, entrance to *second hill*, . . . 938

Pittsburgh Coal, country pit on public road at Lebanon P. O., 984

Pittsburgh Coal, McGowan pit, north-west of Lebanon P. O., 1000

Pittsburgh Coal, country pit at head of Pine Run, . . . 1030

Pittsburgh Coal, Rath country pit, head of Lewis Run, . . 1047

Patterson Summit, east of U. P. Church, . . . 1295

Pittsburgh Coal, pit on Weir farm, on branch of Street's Run, 1038

Pittsburgh Coal, John McKee pit, head of crop on Street's Run, . . . 945

Pittsburgh Coal, Patterson pit, on Patterson branch of Street's Run, . . . 1013

Pittsburgh Coal, Hays' lower pit, (south) east side of Street's Run, . . . 998

Pittsburgh Coal, Hays' water-level drift, north of last, Street's Run, . . . 990

Pittsburgh Coal, west entrance to south tunnel to Hamilton Hollow, . . . 1010

Pittsburgh Coal, east entrance to south tunnel in Hamilton Hollow, . . . 1014

Pittsburgh Coal, west entrance to middle tunnel to Hamilton Hollow, . . . 1018

Pittsburgh Coal, west entrance to north tunnel to Hamilton Hollow, . . . 1012

Pittsburgh Coal, east entrance to north tunnel in Hamilton Hollow, . . . 1012

Pittsburgh Coal, Risher's new opening in branch of Hamilton Hollow, . . . 103

	Above tide.
Pittsburgh Coal, Hill's country pit at head of crop, Hamilton Hollow,	1035
Pittsburgh Coal, Risher's country pit at head of east fork,	1030
Pittsburgh Coal, Miller's pit, in flat, at head of West's Run,	1032

Jefferson township.

Pittsburgh Coal, O'Neill mine, Aber coal, south side Coal Valley,	879
Pittsburgh Coal, at drift on opposite side of Coal Valley,	900
Pittsburgh Coal, at drift at head of Coal Valley, Mifflin township line,	912
Pittsburgh Coal, Foster, Clark & Wood's mine, head of incline,	904
Summit on public road, over Foster, Clark & Wood's workings,	1150
Pittsburgh Coal, rear pit mouth of Foster, Clark & Wood's mine, on branch of Lewis Run,	876
Pittsburgh Coal, Larges country pit, on hill, south side Peter's Creek,	912
Pittsburgh Coal, Walton's lower drift mouth, in ravine back of West Elizabeth,	976
Summit of road at J. Ray's house, limestone,	1131
Pittsburgh Coal, Walton's dilly pit mouth, No. 2, Robinson Run,	946
Redstone Coal bed in road near Tepe school house,	1021
Summit of road, Tepe school house,	1071
Pittsburgh Coal, outcrop in north fork of Lobb's creek, north-east of Converson's store,	901
Pittsburgh Coal, Walton's (upper) Calamity pit,	884
Pittsburgh Coal, Walton's (lower) new Calamity pit,	871
Summit over coal here,	1111
Samuel Heath's flagstone quarry,	956
Shepler's house,	979
Pittsburgh Coal, Shepler's country pit, near Peter's Creek,	874
Pittsburgh Coal, Dr. Finley's pit, about,	870
Pittsburgh Coal, Castor pit, on public road,	869
Pittsburgh Coal, Peirce's pit, opposite side of ravine,	869
Pittsburgh Coal, Hoffman's pit, in hill south side of Peter's creek,	881
Pittsburgh Coal, Bedell's pit, in hill, south side of Peter's creek,	889
Pittsburgh Coal, Bedell's pit, No. 2, south side of Peter's creek,	894
Peter's creek at Larges bridge,	744
Pittsburgh coal, Curry pit, in ravine, east side of Lick Run,	986
Pittsburgh Coal, Hindman pit, in same ravine,	991
Pittsburgh Coal, Doughty pit, east of Cochran's Mill, east side of Lick Run,	1001
Pittsburgh Coal, John A. Mowry's pit,	982

	Above tide.
Pittsburgh Coal, John Snee pit,	969
Pittsburgh Coal, Snee's pit mouth, Gillhall,	996
Pittsburgh Coal, Woodford's pit,	984
Pittsburgh Coal, Beam's Mill,	999
Pittsburgh Coal, Espey's, on Lewis Run,	997
Pittsburgh Coal, Rankin's pit,	991
Pittsburgh Coal, Rankin's old pit,	1003
Pittsburgh Coal, Stewart's pit,	947
Pittsburgh Coal, Chamberlain's,	935
Pittsburgh Coal, old pit on Wilson Run, branch of Lick Run,	943
Pittsburgh Coal, H. B. Wallace pit, near the Snowden township line,	931

Snowden township.

Pittsburgh coal, H. B. Wallace pit near Jefferson line,	931
Pittsburgh Coal, Long pit mouth,	966
Pittsburgh Coal, James Wilson pit mouth, west side of Lick Run,	953
Pittsburgh Coal, McElhaney pit mouth,	969
Pittsburgh Coal, John Wallace pit, west side of Lick Run,	998
Pittsburgh Coal, King's pit, further south,	1027
Pittsburgh Coal, Aber's (Woods) pit,	1017
Pittsburgh Coal, Aber's second pit,	1001
Pittsburgh Coal, Brown's pit,	1015
Pittsburgh Coal, crop at head of Little Piney Fork,	939
Pittsburgh Coal, Glenn's pit, Cat Fish Run,	949
Pittsburgh Coal, Harger's pit, Cat Fish Run,	977
Pittsburgh Coal, Handle's pit, Clydesdale stock farm,	987
Pittsburgh Coal, Miller's pit on Piney Fork,	988
Pittsburgh Coal, Rigg's pit on Piney Fork,	1009
Pittsburgh Coal, Goodboy's pit,	955
Pittsburgh Coal, Bedell's old pit (Pittsburgh & Chicago, No. 1)	922
Pittsburgh Coal, Bedell's new pit, (Pittsburgh & Chicago, No. 2,)	895
Summit, Twelve Mile House, near Washington county line,	1168
Pittsburgh Coal, at Bowle's pit on Library road,	1008
Pittsburgh Coal, Higbee's pit on Library road,	1003
Pittsburgh Coal, Siebold's pit on Library road,	983
Pittsburgh Coal, Potter pit,	933
Library village,	962
Pittsburgh Coal, pit on Brownsville road 400 yards north Twelve Mile House,	1021
Pittsburgh Coal, Nolan pit north side of Piney Fork, on Brownsville road,	1004

Elevations in Lincoln, Elizabeth, and Forward townships.

	Above tide.
Pittsburgh Coal, Hunter's drift, (abandoned,) just south of Reynolds',	940′
Pittsburgh Coal, Miller's opening on ridge road, south of Reynolds',	946
Pittsburgh Coal, Edmindston mine, ¾ miles south of junction of rivers,	956
Pittsburgh Coal, Penny mines,	964
Pittsburgh Coal, McClure coal pit,	998
Pittsburgh Coal, in road north of Phillips' pit,	1060
Pittsburgh Coal, Phillips' country pit,	1088
Pittsburgh Coal, crop in road north of Jenny Lind schoolhouse,	1108
Pittsburgh Coal, Robbins & Jenkins' mine on Monongahela River,	973
Hill summit, Alexander Calhoun's place,	1229
Pittsburgh Coal at Alexander Calhoun's, between forks of Dead Man's Hollow,	1108
Pittsburgh Coal, Crossdale pit, at head of Harper's Hollow,	1098
Pittsburgh Coal, Gumbert & Hewey, rear pit on west fork of Logan's Hollow,	1009
Pittsburgh Coal, O'Neill's (Brown's) mine, head of Logan's Hollow,	999
Pittsburgh Coal, Cornell & Werling's mine, (Brown & Co.,) south of Boston,	989
Pittsburgh Coal, Cornell & Werling's mine, rear pit in Wild Cat Hollow,	895
Pittsburgh Coal, Eagle Nest mine on Youghiogheny river,	988
Pittsburgh Coal, abandoned pit, Duncan's Hollow, on P. McK. & Y. R. R.,	862
Pittsburgh Coal, Dravo pit, near Duncan Station,	847
Pittsburgh Coal, Lake Shore Gas Coal Co., old Ciero mine,	808
Pittsburgh Coal, at Stringtown mines, about	800
Pittsburgh Coal, J. H. Henderson, upper pit on Wild Cat Hollow,	836
Pittsburgh Coal, J. H. Henderson, lower pit on Wild Cat Hollow,	816
Pittsburgh Coal, Daggart's lower pit in ravine, branch of Wild Cat Hollow,	816
Pittsburgh Coal, Daggart's upper pin ravine, branch of Wild Cat Hollow,	821
Pittsburgh Coal, Eicher's country pit, south side of Wild Cat Hollow,	811
Pittsburgh Coal, Eicher's county pit, north side of Wild Cat Hollow,	816
Pittsburgh Coal, South West Gas Coal Co. pit,	810
Pittsburgh Coal, Boyd's Hill mines, Ocean Nos. 3 and 4, W. L. Scott & Co.,	811

	Above tide.
Pittsburgh Coal, ½ mile further south, along P., McK. & Y. R. R.,	816
Pittsburgh Coal, Ocean No. 2 mine, (W. L. Scott & Co.,) on P., McK. & Y. R. R.,	807
Pittsburgh Coal, Atlantic mines, (Bly,) north of Howell's Run,	790
Pittsburgh Coal, Pacific mines, (Bly,) south side of Howell's Run,	819
Pittsburgh Coal, country pit, north side of Howell's Run,	797
Pittsburgh Coal, south or water-pit of Pacific mines on Douglass Run,	81
Pittsburgh Coal, crop west of B. S. S., on Pierce's Fork, Howell's Run,	800
Pittsburgh Coal, Weaver's pit, 4200′ below (north) of Pollock's Run,	838
Pittsburgh Coal, country pit, 500′ below (north) of Pollock's Run,	833
Summit on road below Round Hill Church, head of Pierce's Fork,	1092
Redstone Coal opening at head of Hayden's Run, (Falling Timber Run,)	925
Pittsburgh Coal, country pit, opposite Hilldale Hotel,	888
Pittsburgh Coal, Horner & Roberts, main pit at Hilldale,	879
Pittsburgh Coal, Horner & Roberts, new pit,	882
Pittsburgh Coal, Lovedale pit at Lovedale,	953
Pittsburgh Coal, Morton pit at crop on south branch of Wiley's Run,	908
Pittsburgh Coal, Peter Wedell country pit, north branch of Wiley's Run,	980
Pittsburgh Coal, bottom of shaft, rear workings, of Cornell & Werling mine,	955
Pittsburgh Coal, O'Neill mine, just south of East Elizabeth on Monongahela River,	941
Pittsburgh Coal, Wenona mines, on Leech Creek,	830
Pittsburgh Coal pit at point of hill, north side of Leech Creek,	855
Pittsburgh Coal, Irwin's abandoned pit,	800
Pittsburgh Coal, in ravine ½ mile from river, on L. S. quarry track,	780
Pittsburgh Coal, H. D. O'Neill's mine, (McKnight pit,)	833
Pittsburgh Coal, Gardner pit at Elkhorn,	776
Pittsburgh Coal, Old Eagle mine at Elkhorn,	770
Pittsburgh Coal, Horner pit, ½ mile further south-east,	781
Pittsburgh Coal, Campbell & Bakewell pit,	812
Pittsburgh Coal, Rankin's pit, west of Sunnyside,	760
Pittsburgh Coal, Milesville mines, west or new entry,	790
Pittsburgh Coal, Milesville mines, east or old entry,	780

Elevations in Washington County.

Union township.

	Above tide.
Gastonville village, B. & O. R. R. track,	895
Pittsburgh Coal, at Pittsburgh & Chicago Gas Coal Co., No. 1 mine,	925
Pittsburgh Coal, Murphy pit at Fry's place, south side of Peter's creek at Finleyville,	917
Pittsburgh Coal, at Finley pit, south side B. & O. track, above Finleyville,	971
Pittsburgh Coal, at Rankin (abandoned) pit on Union-Nottingham line,	964
Summit at forks of road south (Mingo creek road,)	1120
"Great Limestone," 200 yards east of cross roads to Cannonsburg,	970
Continuing on south-east dip to Mingo church, at	940
Sewickley (?) *Coal* crop in ravine further south-east, at	855
Redstone Coal, at pumps of Buffalo mines, on Mingo creek,	835
Pittsburgh Coal, at this point, bottom of shaft,	765
Pittsburgh Coal outcrop at Mingo covered bridge,	780
Pittsburgh Coal, Courtney mine, on river at Courtney station,	774
Pittsburgh Coal, at Garfield mine, on Monongahela river,	758
Pittsburgh Coal, at Buffalo mine, on Monongahela river,	755
Pittsburgh Coal, at Cincinnati (new) mine,	757
Pittsburgh Coal, on P. V. & C. R. R., at Huston Run station,	761
Pittsburgh Coal, Coal Bluff mine,	771
Pittsburgh Coal, Cliff mine,	800
Pittsburgh Coal, at Banner mine, No. 1,	816
Pittsburgh Coal, at Banner mine, No. 2,	824
Pittsburgh Coal, at Hilldale mine, near Allegheny county line,	869

Peters township.

Pittsburgh Coal, Legler mine, north-west of Finleyville,	10[illegible]4
Redstone Coal, in Brownsville road north-west of Legler pit,	1089
Great limestone, on hill near Twelve Mile House,	1135
Great limestone, in cut on (abandoned) Pittsburgh Southern R. R., south of Twelve Mile House,	1118
Pittsburgh Coal, Boyer pit, south side of grade, Pittsburgh Southern R. R.,	1038
Pittsburgh Coal, McGowan's (Andre's) pit, south-east of last,	1028
Pittsburgh Coal, Peter's creek, No. 1, mine, near Anderson station, B. & O. R. R.,	984
Pittsburgh Coal, Anderson mine, 100 yards further south-west, north side of Peter's creek,	969

Nottingham township.

Pittsburgh Coal, Nottingham mine, No. 1,	969
Pittsburgh Coal, Nottingham mine, No. 2, 500 yards south,	978
Pittsburgh Coal, Phillips pit, south side of creek at Anderson station,	981

Carroll township.

	Above tide.
Pittsburgh Coal, Mingo mine, at Mingo station, P. V. & C. R. R.,	770
Pittsburgh Coal, Gibson pit, on road up Mingo creek,	770
Pittsburgh Coal, Lofink's pit, beyond grist mill,	780
Pittsburgh Coal pits, south side of creek at Mingo bridge,	780
Pittsburgh Coal, New Eagle mine, on river north-west of Monongahela City,	786
Pittsburgh Coal, Dry Run mine, north of Monongahela City,	811
Pittsburgh Coal, J. Peters' pit, on Pigeon creek, just south of Monongahela City,	790
Pittsburgh Coal, Tullman and Canday pit, Pigeon creek,	798
Pittsburgh Coal, country pit back of race track, Pigeon creek,	803
Pittsburgh Coal, Dr. Van Voorhees' pit, Pigeon creek,	788
Pittsburgh Coal, Haywood's (new) pit, Pigeon creek,	758
Pittsburgh Coal, Clinton Van Voorhees' pit, near crop on Pigeon creek,	738
Pittsburgh Coal, Catsburg (Stibe's) mine, rear pit in Scott Hollow,	758
Pittsburgh Coal, Bolman pit, Pigeon creek, south side,	783
Pittsburgh Coal, Woodward pit, Pigeon creek, south side,	783
Pittsburgh Coal, New Catsburg mine, main (river) pit mouth,	778
Pittsburgh Coal, Ivile mine, (Jones) east of last,	770
Pittsburgh Coal, Black Diamond (Brown's) mine on river,	776
Pittsburgh Coal, Robinson (Hays') mine,	790
Pittsburgh Coal, Old Victory mine, (abandoned,)	784
Pittsburgh Coal, abandoned pit one eighth mile below Baird's station,	782
Pittsburgh Coal, abandoned (second) pit, old Buzzard mine,	790
Pittsburgh Coal, Old Venture mine, Crombie, Skillen & Co., Baird's station,	805
Pittsburgh Coal, Boyle mine, above Columbia,	864
Pittsburgh Coal, Whiteville mine, below Wolf Harbor Run,	883

Allen township.

Pittsburgh Coal at Clipper mine, Allenport,	829
Pittsburgh Coal, Peacock mine, west from Luceyville,	783
Pittsburgh Coal, American mine, west from Luceyville,	783
Pittsburgh Coal, Gregg mine, near Woods Run,	785
Pittsburgh Coal, Champion mine, near Woods Run,	789
Pittsburgh Coal, Caledonia mine,	794
Pittsburgh Coal, Eclipse mine, at East Pike Run township line,	790

East Pike Run township.

Pittsburgh Coal, Dexter mine, on public road,	800
Pittsburgh Coal, Globe mine,	800
Pittsburgh Coal, Reed pit,	790
Pittsburgh Coal, Greenfield pit, below Pike Run, (Neel Mine,)	780

	Above tide.
Forks of Pike Run at bridge,	792
Pittsburgh Coal? about 20' above Pike Run,	812
On Pike Run at second bridge of B. & O. R. R., (projected,)	802
Pittsburgh Coal,? Smallwood Bank, on Pike Run,	842
Pittsburgh Coal at C. Michener pit, Pike Run,	762
Pittsburgh Coal, Chalfant pit, Pike Run,	752
Pittsburgh Coal at Knob Mine Slope, south of West Brownsville,	710
Top of Slope, Knob mine,	778

East Bethlehem township.

Pittsburgh Coal, crop on Monongahela River above Dam No. 5,	750
Pittsburgh Coal, Driftwood Bend Mine, (old Black Hawk,)	762
Pittsburgh Coal, opened at road level,	765
Pittsburgh Coal, Walkins bank,	778
Pittsburgh Coal, Taylor (Dale) pit,	790
Pittsburgh Coal, Crouch pit, abandoned,	803
Pittsburgh Coal, Hancock pit, north of Centreville road,	833
Pittsburgh Coal, Vandegrift pit,	838
Pittsburgh Coal, Bears pit, back of Salt Works,	833
Pittsburgh Coal, Register's and Dan Martin's pits,	833
Pittsburgh Coal, Finnis St. Clair's pit,	838
Pittsburgh Coal, Weaver's pit, below Fredericktown,	833
Pittsburgh Coal, abandoned pit back of Fredericktown mill,	818
Pittsburgh Coal, Mrs. Phillips' pit,	808
Pittsburgh Coal, Montgomery mine, near river bank,	755
Millsboro' Village,	750

Elevations in Greene County.

Monongahela township.

Pittsburgh Coal, mouth of Muddy Run, Cumberland township,	500±
Pittsburgh Coal, mouth of Whitely Creek, about	760±
Pittsburgh Coal, at Gray's house, 25'± below surface,	770?
Redstone Coal? at Gray's Distillery pit,	881
Pittsburgh Coal crop in first ravine south of Lock No. 7,	829
Pittsburgh Coal in old pit south of M. E. Church,	872
Pittsburgh Coal, Stevenson mine,	889
Pittsburgh Coal, Gabler's new pit, north-west of Greensboro',	894
Pittsburgh Coal, Black's bank, ¼ mile west of Greensboro', on Morgantown road,	914
Sewickley (?) Coal, on Mapleton road, above Bobtown bridge over Dunkard's Creek,	950
Waynesburg? Coal, higher up road, (north,)	1100
Coal smut on road near Summit, on township line,	1170
Smut on north side of hill on road descending to Whitely Creek,	1090
Whitely Bridge, near Willow Grove, (*Greene township,*)	915
Willow Grove Hotel, coal smut, (*Greene township,*)	945

	Above tide.
Coal opened (Uniontown?) $\frac{1}{4}$ mile east of Willow Grove,	1075
Coal opened (Waynesburg?) $\frac{1}{2}$ mile east of Willow Grove,	1155
Whitely Bridge at Mapleton,	885
Sewickley Coal, opened near creek level,	870
Coal crop on Morgantown road, 1 mile west from Greensboro',	935
Pittsburgh Coal, (Williams'?) opened in road,	910
Pittsburgh Coal, 100 yards further down run,	910
Pittsburgh Coal, third (Williams') opening,	922
Hotel at Greensboro' 30′ above river, about	804

Dunkard township.

Dunkard Creek Bridge,	789′
New school-house on Wiley P. O. road,	1008
Wiley P. O. cross-roads, (State Road intersection,)	968
Sewickley Coal, south 25 yards from cross roads,	993
Pittsburgh Coal, crop on Taylorstown road,	880
Pittsburgh Coal, old pit further west along road,	875
Pittsburgh Coal, South mines at Maple Mill,	855
Pittsburgh Coal, pit 200 yards down Dunkard Creek,	855
State Line and Center school house,	1020
Coal on State Road near here,	1046
Pittsburgh Coal, Garlow's mine, south side Crooked Run, (Virginia?)	991
Pittsburgh Coal, Maple Bank, south side Crooked Run, (Virginia?)	986
Rosedale village, at Maple House,	958
Coal crop 1 mile north of Rosedale, on State Road,	1118
Coal crop 200 yards beyond road to right,	1008
Bobtown bridge over Dunkard Creek,	828
Pittsburgh Coal, at Bobtown,	840

Elevations in Westmoreland County.

Rostraver township.

Pittsburgh Coal, at old pit of Beckett's Run mine, on county line, above Milesville,	780
Pittsburgh Coal at new opening, same mine, 150+ yards south,	803
Pittsburgh Coal at water-pit of same mine, 300 yards further south,	810
Pittsburgh Coal, at Paynetown mine, further south on river,	855
Pittsburgh Coal, Gilmore mine, just *north* of Webster,	870
Pittsburgh Coal, Webster mine, just *south* of Webster,	880
Pittsburgh Coal, Columbia mine, opposite Columbia,	930
Pittsburgh Coal, Iron City mine, just south of last pit,	940
Pittsburgh Coal, Rostraver mine, just above Dam No. 4,	968
Pittsburgh Coal, outcrop at Gibsontown, about	1010
Pittsburgh Coal, Robinson's pit, on west branch of Pollock's Run,	841

	Above tide.
Pittsburgh Coal, outcrop in east (main) branch,	785
Pittsburgh Coal, Hill's pit, 300' down creek,	795
Pittsburgh Coal, Kreps pit, Youghiogheny River, near end of outcrop,	761
Top sill of air shaft, West Newton Coal Co., ½ mile below West Newton bridge,	779
Pittsburgh Coal, bottom of shaft,	707
Pittsburgh Coal, bottom of Lisbon Synclinal at Port Royal, about,	650±

Sewickley township.

Pittsburgh Coal, Youghiogheny Coal Hollow Co. pit, at ovens,	782
Pittsburgh Coal, Main tunnel Shaner Gas Coal Co.,	795
Pittsburgh Coal, South pit of Rafferty mine, Shaner Station,	795
Pittsburgh Coal, country pit in Greenawalt Hollow,	795
Pittsburgh Coal, Rafferty pit, Armstrong Station, B. & O. R. R.,	803
Pittsburgh Coal, Ocean mine, No. 1, Scott Haven,	793
Pittsburgh Coal, pit back of Suter Station,	833
Pittsburgh Coal, Black Bear mine, (Bigley's) present main tunnel,	836
Pittsburgh Coal, Bigley's Coal, near check-house,	835
Pittsburgh Coal, Markle pit,	825

North Huntington township.

Pittsburgh Coal, Yough. & Ashtabula mine, (Bly mine,)	782
Pittsburgh Coal, Robbins & Jenkins (abandoned) mine,	797

Miscellaneous levels furnished by J. Wainwright, Esq.

New Geneva, grading in village, Fayette county,	800
Walnut Hill, Fayette county,	1200
Uniontown, Fayette county,	977
Vance's Mill, P. McK. & Y. surveys,	927
West Leisering, P. McK. & Y. surveys, Fayette county,	1006
Beeson's Summit,	1181
East Leisering,	987
Trotter Works,	975
Broad Ford,	874
Dickerson Run,	853
Morris cross-roads,	1150
Point Marion,	800
Robbins' coal tipple on Monongahela River,	751.7
Top of rail, Gumbert & Huey tipple,	756.78
" " Lovedale R. R.,	749.7
" " Horner & Roberts R. R.,	751.24

Elevations in Fayette County.

	Above tide.
Washington township.	
Pittsburgh Coal, Little Pittsburgh mine, 1 mile above Belle-vernon,	838
Pittsburgh Coal, Connecticut mine, Fayette City,	779
Pittsburgh Coal, Little Redstone mine, just above Fayette City,	783
Pittsburgh Coal, Carondelet mine, (formerly Frazer & Fry,)	786
Jefferson township.	
Pittsburgh Coal, Germania (old Turnbull) mine,	780
Pittsburgh Coal, Excelsior works, Troytown,	784
Pittsburgh Coal, Bargeddie mine,	776
Pittsburgh Coal, Snow Hill (Alps) mine,	776
Pittsburgh Coal, Little Alps, No. 1, (Merchant mine,)	772
Pittsburgh Coal, " " " 2, (Budd mine,)	770
Pittsburgh Coal, Cedar Hill mines,	772
Pittsburgh Coal, Garrow's bank, abandoned,	767
Pittsburgh Coal at Climax (Leonard) mine, ¾ mile below Redstone Creek,	738
Albany (Snowden) mine slope, 778'; *Pittsburgh Coal*, about	748
Pittsburgh Coal at old glass works,	758
Pittsburgh Coal, 100 yards south of Albany slope,	768
Pittsburgh Coal, Umpire mine, Brownsville,	780
Luzerne township.	
Pittsburgh Coal, Evans mine, near Fredericktown Ferry,	768
Pittsburgh Coal, Jacobs slope, above Wallace's Run,	650±
George's township.	
WEST SIDE OF FAYETTE AXIS.	
Pittsburgh Coal, Gray's distillery, country pit on Cat's Run,	870
Pittsburgh Coal, Johnson's place, country pit, two miles from river,	990
Pittsburgh Coal, country pit near Mennonite church, 2¼ miles from Cat's Run,	1010
Pittsburgh Coal, country pit near end of crop on Cat's run, three miles from river,	1054
Pittsburgh Coal, country pit north-west of Lutheran church, head of crop,	1120
Pittsburgh Coal, crop on road leading north-east from Lutheran parsonage,	1170
Pisgah, on south branch of Brown's Run,	1320
Pittsburgh Coal, Parshall pit, north branch of Brown's Run,	1018
Pittsburgh Coal, country pit near forks of Brown's Run,	956

East Side of Fayette Axis.		*Above tide.*
	Pittsburgh Coal pit on south branch of Brown's Run, near Georges township line, ...	1172
	Pittsburgh Coal, Dawson pit, on Brown's Run, one third of a mile from German township line, . .	1118
	Walnut Hill summit, near school house, No. 5, ...	1220
	Pittsburgh Coal pit at head of crop south-east of Fleatown, ...	1150
	Pittsburgh Coal, north of school house, No. 8, at Smithfield, ...	1100
	Cross roads at Smithfield, ...	1180
	Pittsburgh Coal crop just east of Smithfield, ...	1084

Nicholson township.

Pittsburgh Coal, country pit, Kefvoer?, ...	1071
Pittsburgh Coal, above Longnecker's place, north side of branch of Cat's Run, ...	1070
Pittsburgh Coal, Longnecker's place, south side of branch of Cat's Run, ...	1062
Pittsburgh Coal in ravine just north of E Walters' place, at head of branch entering Cat's Run at saw-mill, about 1½ miles from river, ...	890
Pittsburgh Coal crop in next branch west, ¾ miles south from Cat's Run, ...	850
Redstone Coal, opening near mouth of Cat's Run, ...	891
Pittsburgh Coal, at "Cat's Run mine," on river front, . . .	812
Pittsburgh Coal, at Ewing and Kendall mine, ½ mile south,	842
Pittsburgh Coal, Parshall opening just north of Jacob's creek,	842
Cross road at forks of Jacob's creek. 1½ miles from river, . .	900
Pittsburgh Coal in pit on Fast's branch, south of S. Cover's place, ...	1000
Coal crop (*Sewickley?*) at turn of road below Fast's house, .	1095
Summit on road at German Baptist church, (Great L. S.,) .	1170
Pittsburgh Coal(?) crop at John Cover's lane, on public road,	1075
Pittsburgh Coal(?) Phillips' pit south of road, head of south branch of Jacob's creek, ...	1120
Pittsburgh Coal, Anderson pit, Cross Roads north of Presbyterian Church, ...	1160
Pittsburgh Coal, Monaghan pit just north along road from last, ...	1165
Pittsburgh Coal, crop near school house, No. 5, head of War Branch Run, ...	1075
Pittsburgh Coal, Morris pit west of Crow's Mill road, ...	1100
Pittsburgh Coal, abandoned pit north side of hill from last pit,	1095

(NOTE.—The Fayette axis passes about one half mile east from these two last pits, with none of the Pittsburgh bed between.

The south-east crop into the Connellsville basin lies one half mile east of the axis.)

	Above tide.
Pittsburgh Coal, crop near A. Crow's Cross Roads to Geneva, ½ mile from river,	1060
Pittsburgh Coal crop ½ mile north-west, at Joseph Hess',	983
Pittsburgh Coal, crop on river front at ferry ¾ miles south of Jacob's creek,	930

Springhill township.

Bridge at Hunter's Mill on George's creek,	890
Pittsburgh Coal, below school house on Point Marion road, one mile from the mouth of George's creek, opposite Greensboro', and 316′ above river, at	1090
Sewickley Coal, or "Five foot vein," near summit, Provence's house,	1190
Pittsburgh Coal, "Nine foot vein," Grimes' pit, near public road,	1130
Pittsburgh Coal, Sackett pit,	1150
Redstone? Coal, near Cross Roads to Marion & Morris' Cross Roads,	1180
Sewickley (?) Coal, on summit 200 yards beyond,	1225
Pittsburgh Coal, T. J. Burchinal pit, Cheat river road, below B. S. S.,	1160
Pittsburgh Coal, A. J. Gans pit, beyond Methodist Church,	1165
Pittsburgh Coal, A. Crow, opened on both sides of ravine,	1170
Pittsburgh Coal, M. Crow pit, below school house,	1165
Pittsburgh Coal, Al. Scott, next opening east of last, along road,	1150
Pittsburgh Coal, John Lynn's, near Morris Cross Roads,	1125
Morris Cross Roads, at hotel,	1150
Pittsburgh Coal, T. I. Scott pit, 200 yards north-west,	1105
Sewickley Coal, south along road to Lutheran Church,	1215
Sewickley Coal, second crop beyond church, at	1210
Pittsburgh Coal, Hill's pit, opened in bluff above Cheat river,	1050
Pittsburgh Coal, crop on T. Lyon farm, one mile south-east of Morris Cross Roads,	1095
Pittsburgh Coal, Fast's bank, near old school house, head of Grassy Run,	1100
Pittsburgh Coal, A. Stewart pit, north-west on branch of George's creek,	1110
Pittsburgh Coal, crop on road near J. Hard's place, north side of same branch,	1120
Coal crop and limestone, eight inches, in road south of Hunter's Mill,	930
Pittsburgh Coal, at head of George's creek, near C. W. Brown's place, and close to the George's township line,	1026

Chapter II.

Geological Structure.

The structural features of the territory now under discussion will appear upon an examination of the page plate map (page 126) and the more detail map accompanying this preliminary report.

The value and usefulness of this latter map are greatly enhanced by the property surveys of R. M. McKinney, M. E., which were kindly placed at my disposal, and which have been reduced one half to the present scale, 200 rods = 1 inch.

To the portion furnished by Mr. McKinney, I have added material to carry the map northwards to McKeesport, and along the two rivers, both to render the map more complete and comprehensive, and to more clearly show the occurrence of the *Peters Creek Axis.* The reëstablishment of this axis, first located by Prof. J. J. Stevenson in his report K, on Greene and Washington counties, and afterwards repudiated in his later report KK, on Fayette and Westmoreland counties, seems to be inevitable.

Its extension far south-west of the country lying between the two rivers, seems to be as indefinite and obscure as it was in 1876; but it is highly probable that the Washington county line, along the southern border of Jefferson township, in Allegheny county, fairly limits its extent in that direction.

Certainly no surface evidences of its presence in Washington county can be detected between the Monongahela River and Peters Creek, the coal from the Coal Bluff and other mines on the river front lying nearly level or rising north-west with but little interruption to Peters Creek.

Evidences of the existence of this axis, however, in Jefferson township, from a point a little south of Lock No. 3 to where it leaves the township north of Blair Station on the P. V. & C. R. R., are apparent.

Its decline in approaching Washington county has no doubt caused the westward erosion of the river, as its presence at Blair Station has certainly affected the course of the Monongahela there; likewise of the Youghiogheny south-east of McKeesport.

It will be observed that in restoring this Peters Creek axis, I have also shifted its position south-eastward, instead of passing it through the *mouth of Peters Creek*, according to report K, page 29.

The reasons for this are obvious; and despite the limited outcrop of the Pittsburgh coal-bed contained on the map, its presence between the two rivers is plainly made out.

All the coal along the *south* side of the Monongahela River lies lower than that *north* of the river along the crop, therefore the dip is *south-east* between the two outcrops.

In whatever position the coal lies in the hills along the river front above the Monongahela division of the P. R. R., for P. V. & C. R. R., (and the probability is that it is very flat,) we know, from actual development, that it soon dips to Peters Creek, the crop there being anywhere from 50 to 70 feet lower than on the river, though a large "swamp" has been developed in the Walton workings close to the creek crop.

The same features are repeated further west where, the *Hilldale Mine coal* at 869 A. T. is practically at the same level as the several country pits opened on Peters Creek, opposite the mouth of Lick Run. From Hilldale (Washington county) the coal dips *north-west;* from Peters Creek, decidedly *south-east*, the trough between carrying a swamp. From Peters Creek everything rises rapidly north-west to the Pin Hook axis.

So much for the region immediately north-west of the one under discussion.

Crossing the river near Blair's Station, the course of this anticlinal for the next 1½ miles to the Youghiogheny at Long Run Station, on the B. & O. R. R., can be followed on the map.

Some idea of its strength and prominence can be gained from a comparison of the coal levels on or near its crest,

and in the resulting synclinal basins north-west and south-east.

From the axis to the outcrop of the Pittsburgh Coal south of Reynolds, (McKeesport,) is, in an air line, 2¼ miles, the difference in coal level being fully 170 feet, or about 75 feet per mile.

From the axis south-east to Buena Vista is about 4 miles, and the difference in coal elevations 300′ or an equal rate per mile of 75 feet.

In Versailles township, on the north-east side of the Youghiogheny, there is hardly any Pittsburgh coal left, the whole township being eroded and furrowed down by Long and Jack's Runs, and exposing little else but the Barren Measures.

What few isolated patches have been left east of Jack's Run, and along the Westmoreland county line, all evince a strong *south-east* dip, while, at the same time, rising to the *north-east* in obedience to the general laws governing the rise in that direction of the plane of the various axes of this district. The exact position of the axis in this township beyond the Youghiogheny River cannot be located, in the absence of some key rock; but in North Versailles township, it crosses the Pittsburgh and Greensburg pike not far from the M. E. Church, and within 700 yards of the Westmoreland county line.

Miller's coal here is nearly 1200′ A. T., and in 2 miles north-west the coal falls 160 feet.

A barren streak divides this coal from the basin in North Huntingdon township, Westmoreland county, the axis extending north-east to the Penna. R. R., between Carpenpenter's and Stewart's stations, following Turtle Creek to Murrysville, and thence to Roaring Run on the Kiskiminetas River.*

In restoring the Peters Creek axis, therefore, to its place in the district, we can omit the new name, which, after all, is not very appropriate, and simply call it the *Roaring Run* or *Murrysville axis.* Its importance cannot be over-

*The sixth axis of the report of 1858.

looked, and in the development of Natural Gas upon the "anticlinal theory," this axis has been more prominently brought forward than any other within the vicinity of Pittsburgh, owing to the large and productive wells located on or near it at Murrysville, Westmoreland county.

Its rate of rise north-eastward through Allegheny county is very marked. Taking the Pittsburgh bed as a basis, the rate between where it leaves Washington county and where it enters Westmoreland, is fully 27′ per mile, the coal levels being respectively 860′ and 1200′ A. T., and the distance in round numbers through Allegheny, 12 miles.

The detailed map accompanying this report embraces the territory between the *Lisbon synclinal* on the south-east, and the *Pin Hook anticlinal* on the north-west, and between the Monongahela river at Braddock, and the south line of Rostraver township, Westmoreland county.

From the elevations of the Pittsburgh coal-bed at the various mines of the district, and the different mine records, I have endeavored to further illustrate the structural features by reproducing in contour lines, 50 feet vertically apart, *the bottom of the Pittsburgh Coal-bed.* These lines are shown in *red* on the map; the exposed outcrop of the coal in *black.*

From the small map, (page 126) it will be observed that five distinct anticlinals have been traced, trending north-east and south-west across the district, but not always parallel nor coëxtensive one with another in that direction; nor do they describe perfectly straight lines, showing rather a disposition to curve towards the east in the northern part of the field, and towards the south along the Virginia State Line. With but few exceptions the anticlinal crests all rise going north-east, elevating successively lower measures in that direction.

1. *Washington or Brady's Bend anticlinal.*

The first well defined fold, of the district, south of the Monongahela River, is the Washington Axis, so named from the borough of that name in Washington county.

Comparatively little attention was paid to tracing the course of this axis during the past season, owing to demands

on my time in the river region to the south-east. However, its position is well defined in Washington county, passing west of Washington and near Cannonsburg and Ewingsville on the Chartiers R. R.; entering Allegheny county about a mile west of Chartiers Creek, on a nearly N. 45° E. course, cutting Upper St. Clair township nearly in half; passing through Mt. Lebanon, in Scott township, and thence along or parallel with the Washington pike to the city limits at South Pittsburgh, where its cessation forms a broad plateau of the Pittsburgh coal-bed 1000'+ above tide. Its rate of rise in Allegheny county, going north-east, north of the river, is about 22' per mile.

Its position is very well defined on both McLaughlin's and Panther runs, where the Pittsburgh bed is exposed on its arch at respectively 868' and 887' above tide.

In the ravine of Saw Mill run, below the borough of West Liberty, this coal shows at 981', and in the flat north of Beltzhoover borough, its greatest elevation is about 1040'. This axis, if extended, would meet the river below the Birmingham bridge; but, in the flat already mentioned, it is over-ridden by the south-western prolongation of the Brady's Bend axis, which latter may be considered as the extension of the Washington anticlinal through northern Allegheny county, *west* of the Allegheny River, into Butler and Armstrong counties. (See map, page 126.)

This portion of the arch, under the name of the Brady's Bend axis, enters Allegheny county, according to Professor White, (Report Q page 20) in West Deer township, passes west of Culmersville, and crosses Big Deer creek just above Martin's coal works, where the Upper Freeport coal is exposed in the bed of the creek.

It then crosses Pine creek near the mouth of Gourd-head run, bringing the Upper Freeport bed 50' above the stream, and keeping it exposed for three miles along the same.

Girtie's run is crossed at the forks of the stream above Evergreen, and the axis reaches the Ohio River at the mouth of Wood's run, three miles below Pittsburgh. Instead of breaking there and shifting south-east to Temperanceville, it seems to bend slightly toward the south, cross-

ing the Panhandle R. R. just east of the tunnel and Sheridan Station and is visible as an axis as far south-west as the Idlewood Hotel, about 3 miles from the river, and about ½ mile east of Idlewood Station, on the Pan-handle R. R.

There is certainly a reversal of dip at Sheridan Station, depicted in the Crinoidal limestone and accompanying rocks of the Barren Measures, the Pittsburgh coal being in the hill tops 1100′ above tide.

One mile to the south-west, the Pittsburgh bed is opened on the plank road at Wettengill's and Gormley's country pit at 1080′, dipping south-east, and at Hodgson's pit at 1090′, dipping north-west on opposite sides of the axis.

At the Craft and Phœnix pits, 1052′ and 972′, the dip is north-west into the Mansfield synclinal; while at the Sterrett pit, 978′, 1½ miles from the railroad, the dip is south-east.

On Whisky Run, further south-west, no change of dip was observed, all the coal draining directly from the Washington axis north-west into the Mansfield synclinal.

Prof. White calculates the rate of fall south-west of this Brady's Bend axis north of the river at 22′ per mile on a S. 40° W. course, though south of the Ohio River, its decline is much more rapid, falling from 1100′ to about 960′ A. T. on the arch east of Idlewood Station, or 140 feet in a little over 2 miles.

Economically, this axis is a very important one, and it will be referred to in greater detail in the final report.

2. *Pin Hook anticlinal.*

The Pin Hook axis, the next prominent roll in the measures, is a broad arch, perhaps a mile wide, and makes practically a straight line S. 30° W. from the Monongahela River, opposite Braddocks, to the Washington county line 4½ miles from the river. Beyond this line, to the south-west, its course has not been traced, though from the uninterrupted north-west rise of the measures from Peters Creek at Finleyville, past its prolongation into Washington county, it is quite probable that this axis has lost its prominence, to rise again south-east at Dunningsville, and thence

on to Pin Hook village in Amwell township, as shown on the page-plate.

North of the Monongahela River its course is likewise broken, taking in again 2 miles west of Braddocks, in the vicinity of North Homestead. From here it takes up a parallel north-east course through Wilkinsburg and Sandy creek, crossing Pucketa creek more than a mile from the Allegheny River, and merging into the Bagdad axis near Brady's run on the Kiskiminetas River.

Its course is largely marked by exposures of the Barren Measure rocks along Nine Mile run and through North Penn and Plum townships; the Pittsburgh coal everywhere dipping from it to the south-east into the trough of Turtle creek and Thompson run in the Leechburg synclinal.

3. *Roaring Run (Peters Creek)—Murrysville anticlinal.*

The position of the *Roaring Run* (Peters Creek) axis, between the Washington county line and the Pennsylvania R. R., is likewise clearly illustrated on the maps, and makes a slight angle with the Pin Hook axis. In that distance—about 12 miles—its crest subsides about 350 feet, until it dies away in Washington county altogether, and allows the Pittsburgh coal to swing over its arch.

Its extension north-eastward is in a direct line with the Murrysville axis to Roaring run on the Kiskiminetas River. It has already been described in detail.

4. *Waynesburg anticlinal.*

The Waynesburg anticlinal, about 7 miles to the south-east, is only partially shown on the large map, but its general course and position are indicated on the page-plate. From Waynesburg to the Monongahela River, which it crosses about 1½ miles below Bellevernon, it describes a practically straight line for about 24 miles.

Between the two rivers its course is curved slightly to the north, meeting the Youghiogheny River just below Pollock's run, in Elizabeth township. Here its course is bent to the east again, trending east of Sewickley Creek and

through Westmoreland county to the village of Grapeville; thence west of Harvey's Five Points to the Kiskiminetas at Saltsburg.

While it shows the same general rise going north-east, this increase is interrupted between the two large rivers, as shown by the contours on the map, falling, going north-eastward, in that section about 150 feet in 8 miles. It is owing to this decline that its position is so obscure, and its effect so insignificant, on the Youghiogheny River.

North of the Youghiogheny it again commences to rise gradually to the Kiskiminetas. Under the names of *Waynesburg axis*, *Brush Ridge*, *Grape Ridge*, it makes apparently one and the same axis with the Saltsburg anticlinal to the north.

5. *Fayette anticlinal.*

The *Fayette anticlinal* is the last prominent axis of the district under survey. This is the axis flanking the Connellsville Basin on the west. While it has not been possible to give it as much attention as some of the others, sufficient has been done to warrant its association with the *Indiana* (Blairsville) *axis* of Indiana and Westmoreland counties, rather than with the Saltsburg anticlinal, as has been heretofore accepted.

However, more detailed work will be necessary before this point can be definitely settled, and the acceptance of this structure at present is wholly provisional.

The course of this fold through Fayette county, between the State Line and the Yougiogheny River, is fairly well developed. In Spring township it lifts the Pittsburgh coal about 380′ above the Cheat River, passing thence west of Morris Cross Roads and Smithfield, in George's township, to the Redstone creek, about 7½ miles above its mouth.

Keeping a direct course north-east, it passes close to Flatwood P. O., and meets the Youghiogheny River at Virgin's run. Between this point and Carr's Tunnel, on the P. R. R., its position is obscure, owing largely to the eroded character of the country and the difficulty of assigning it a

position in the Barren Measures, here largely composing the exposures.

At Layton Station, however, on the B. & O. R. R., the presence of an axis is clearly made out, which can be traced to Jacob's creek. Its north-east prolongation to the P. R. R. is therefore interpolated on the map, coinciding from there with the Indiana (Blairsville) axis to the Kiskiminetas below Blairsville.

The principal synclinal basins of the district are four in number, contained between the five anticlinal folds, the Mansfield synclinal flanking the Washington axis on the north-west and not at present under discussion.

Beginning at the north-west we have:

1st. The *Nineveh-Allegheny River synclinal*, between the Washington-Brady's Bend axis and the Pin Hook-Bagdad axis, passing through Freeport at the junction of the Allegheny and Kiskiminetas Rivers, and merging into the double Nineveh basin south of the Monongahela River.

2d. The *Leechburg synclinal*, between the Pin Hook and Roaring Run axes. On the Kiskiminetas this basin is split by the Apollo sub-axis into *Leechburg* basin on the west and *Apollo* on the east.

On the Monongahela River no subordinate axis occurs, so that the measures dip without interruption into the Turtle creek and Thompson run trough.

South of the river however a subordinate roll creates the Nineveh and Street's Run synclinals west of the Pin Hook axis; but on the east side of the main axis, there is no reversal of dip into the southern basin, which will be seen on the map describing a sinuous course from a point north of Lob's creek, on the Washington line; crossing Peters creek above the mouth of Lewis run; the Monongahela River near Moss Side Station; thence following the channel of the river to a point above Port Perry and there joining the Turtle Creek trough between Wilkins and Patton townships.

From McKeesport the coal rises north-west to the Pin Hook axis, about 55 feet per mile, and south-east on to the Murrysville axis at the rate of about 75′ per mile.

3d. The *Waynesburg synclinal*, between the Murrysville and the Waynesburg axis.

This is the Irwin basin of Westmoreland county, passing from the big bend in the Kiskiminetas at the Indiana-Armstrong county line, through Irwin's Station, on the P. R. R., to Guffey's Station on the Youghiogheny and through the channel of that river, to Howells run.

In Allegheny county it is split by the Monongahela sub-axis. The southern trough passes through the south-eastern portion of Forward township to Milesville, on the Monongahela, and thence along the channel of that river to Pigeon creek, where it takes up a course nearly parallel to the Waynesburg axis. The northern division is complicated by reason of the subsidence of the Murrysville axis, forking near Courtney Station, on the P. V. & C. R. R., merging northwards into the Peters creek trough, and southward into the trough developed by the workings at the Old Eagle and Horner & Roberts mines.

The continuation of this trough south-west of the Monongahela River is obscure from lack of development.

The entire basin near the river, between the two main axes, is over 10 miles wide, and about 250 feet deep.

4th. The *Lisbon synclinal*, between the Waynesburg and Fayette axes, the deepest basin (geologically) of the series, is likewise divided, at least in Allegheny county, by a subordinate anticlinal passing through the mouth of Muddy creek, with the effect of pushing the Waynesburg and Fayette axes much farther asunder in Greene county than they are in Westmoreland county.

This is the Greensburg basin of Westmoreland county, passing through Port Royal, on the Youghiogheny, where the Pittsburgh coal is deeply buried; through Brownsville, on the Monongahela, and thence south-west into Greene county.

Through a great portion of this basin the Upper Barren Measures are inclosed. It is about 8 miles wide on the Kiskiminetas and Youghiogheny Rivers; 12 on the Monongahela, and 18 in Greene county.

It is about 300′ deep along the Monongahela River.

These basins are, for the most part, quite irregular in form and trend: divided by subordinate axes, and curving or shifting with the folds which created them.

Practically considered, the presence of these subordinate axes in the coal basins is the most fertile cause of mining disaster, for they can neither be closely located from surface indications, nor can their amount of displacement be calculated or discounted in advance of development. It seems quite probable that they are frequently to be regarded as the adjuncts of many of the "swamps" so common to this region, for it would appear that several of the largest and most continuous of these swamps are but subdivisions of the main basins.

This feature will be better understood by reference to the contour map, where it will be seen how the Waynesburg synclinal is split in two by an axis passing through Monongahela City towards Scott's Ocean mine, No. 2, north of Industry, creating on both sides of it the prominent swamps at Old Eagle and Courtney, and those recorded in the series of mines between Pigeon creek and the Westmoreland line along both sides of the river.

So, likewise, the river mines near Elizabeth, whose gangways bear towards the basin along Peters creek, have developed a line of "swamp" between the Murrysville axis and the outcrop along the south side of Peters creek.

The main depression, conspicuously noticeable in the Walton mines, has a general bearing parallel to the Murrysville axis, and lying within a short distance of the Peters creek outcrop.

It has been located in the various gangways of Walton's works from the north-east crop on Scotia run at about 915′ A. T., south-west for over a mile, and declining in that direction about 30′ per mile. Its association with the synclinal trough at Lob's run and Peters creek is suggestive.

Further north-east along this trough a precisely similar effect takes place in O'Neil's Coal Valley works, only the line of "swamp" bears more nearly south, owing to the change of direction in the basin line. The bed of the Pittsburgh coal at this point is excessively irregular. In the

double entry pit, at 879′ A. T., the coal pitches south-west 3′ in 100′, rises to a level, and again dips back into the synclinal. Of course this abnormal difference in elevations is only local; but the line of disturbance is allied to, and located in, the trough.

A couple of hundred yards to the north-west, up stream, the Pittsburgh bed is again opened by the same company at 912′ A. T. Here the gangway is driven north-west, and up the south-east slope of the Pin Hook axis, and no trouble of any kind has been experienced.

Further evidence is afforded in the workings of Foster, Clark & Wood, further south-east, where the bed falls 31′ in 750′ in the main gangway. Here the swamp entry is turned off nearly due west, and so bears directly for the synclinal.

It is not proposed to dwell at length upon this subject at present, nor is there sufficient data at hand to draw any but the most general conclusions.

But the general relationship of "swamp" lines and synclinal troughs seems as probable as it is natural.

A notable exception to this rule, however, will be referred to later in describing the Lovedale mine, in Lincoln township, where the direction of the swamp (S. 35° E.) is transverse to that of the Waynesburg synclinal.

A glance at the underground contouring of the Pittsburgh bed at that place will display its effect as well as the singularly diversified structure of the basin. Whether this structure, which, after all, is but provisional on further development, be peculiar to this trough, or whether all the basins in this district will be found warped and branching, as this one does, it is idle now to speculate upon.

If the many able and expert mining engineers of the district will only note and record all facts bearing upon this question, and plat their notes carefully to scale, so that the levels of one mine can be compared with another, I believe much light can be shed upon the cause and effect of these "swamps." It is well known that they do occur, and to the serious detriment of mining plans.

CHAPTER III.

General Geology; Upper Productive and Barren Measure Series; features of the Pittsburgh Coal Bed, etc.

It seems hardly necessary to repeat in detail the classification of the coal measures of the district, especially in this preliminary report. In the reports on Greene and Washington counties (K.) and Fayette and Westmoreland counties (KK,) this subject has been minutely and skillfully gone over by my predecessors in this field, and I would refer to those two reports as containing all that is necessary for a complete understanding of the rock systems of these counties.

In the special district under consideration in this report, the limit of measures above and below the Pittsburgh Coal bed may be placed at 280′; that is to say that nowhere in the three townships of Lincoln, Elizabeth, and Forward, are there more than 280′ of the Upper Productive coal Measures *over* the Pittsburgh bed, nor more than that amount of Barren Measures beneath it.

The *Upper Productive Measures*, from the *Pittsburgh Coal* to the *Waynesburg Sandstone*, inclusive, may be assigned a general thickness, in round numbers, of 475′, varying, according to Prof. Stevenson's section below, from 458′ to 487′ feet.

The five coal-beds of this series are in the main persistent, though only one of them, the *Pittsburgh Coal*, can be said to be constant as to thickness, quality, and commercial importance.

Section of Upper Productive Coal Measures. K, p. 57.

	Thickness.	Total.
1. Waynesburg Sandstone,	70′	82′
2. Shale,	0 to 12′	
3. *Waynesburg Main Coal-bed,*		6′
4. Fire-clay,	3′	88′
5. Sandstone,	20′	
6. Limestone,	5′	
7. Sandstone and shale,	60′	
8. *Uniontown Coal-bed,*		1′ to 3′
11. Limestone and shale, } Great Limestone	18′	173′
10. Sandstone and shale, } Great Limestone	60	
9. Limestone and shale, } Great Limestone	55′	
12. Sandy shale,	40′	
13. *Sewickley Coal-bed,*		1′ to 6′
14. Sandstone,	10′	53′
15. Limestone,	18′	
16. Sandstone or sandy shale,	25′	
17. *Redstone Coal-bed,*		1′ to 4′
18. Limestone,	10′	60′
19. Pittsburgh (Upper) Sandstone,	40	
20. Shale,	0 to 10′	
21. *Pittsburgh Coal-bed,*		5′ to 12′
		458′ to 487′

The horizon of the *Uniontown Coal-bed* is only met with in one or two places throughout these three townships. This coal and the overlying measures, are not well developed except where the sinking of the measures, to the southwest, brings them into the hill-tops of Fayette and Greene counties, and where they are covered up by still higher rocks belonging to this same series and the overlying Upper Barren Measures.

Strata Nos. 9, 10, and 11 of the section, constituting the "Great Limestone" of the series, have, however, been noted at several places.

The *Uniontown Coal* rests directly upon the upper member of the limestone (No. 11) which varies from 10 to 18 feet in thickness. It has a bright buff color, and is probably present at Round Hill Church, and in the high ridge north of Monongahela City, in Allegheny county. In a general way, however, it may be said to be absent north of the Allegheny-Washington line. The lower division, 30 to 50 feet thick, is still more noticeable, always weathering

into hard angular pieces, and carrying both dolomitic and pure limestone layers. It is quarried in several places in the district, but attains far greater prominence to the southwest.

The *Sewickley Coal*, No. 13 of the section, cannot be noticed in this part of the field, and if it exists at all here, it is represented by a black shale, commercially worthless.

This coal-bed is extensively mined for local use on Dunkard and Whitely creeks, in Greene county, where it shows two benches, the upper 2′ thick; the lower is 3′ 4″ thick and is separated from the upper by a small clay-slate parting.

This same bed is known as the "Five-Foot Seam" in Fayette county, south of the Youghiogheny, where it is considerably mined.

The limestone, No. 15, between the *Sewickley* and *Redstone* beds, is known as the *Fishpot Limestone*, and carries a sandstone above and below it. It was nowhere noticed in this district, and it is doubtful if it exists here.

The *Redstone Coal*, No. 17, though very variable in thickness and generally worthless as a commercial bed, is still very persistent, and can usually be found as a slaty coal or shale from 40′ to 50′ above the Pittsburgh coal. Unlike the other coals of the series, this bed seems to gain importance and thickness coming northward; south of Monongahela City it is everywhere an insignificant bed of shale or dirty coal, from 12 to 18 inches thick. From Monongahela City, north to within the boundaries of southern Allegheny, it is thicker and better, and shows from 1 to 4 feet of coal.

In some portions of Fayette, on the Redstone and Jacob's Creeks, it becomes mineable. Its occurrence between the two rivers, south of McKeesport, will be duly noted in a succeeding chapter.

The Pittsburgh Coal-bed.

The *Pittsburgh coal-bed* is economically the most important of all the coals above or below it, and the only one that can be called persistent as to thickness and quality. It is the best and most valuable seam of the Pennsylvania bituminous coal area.

It is always of mining thickness and excellent quality at all exposures, varying from about 3 to 9 feet thick. This, combined with its almost uninterrupted and accessible outcrop along the Monongahela River, from the State Line to Pittsburgh, renders its development easy and accounts for its commercial supremacy over wide areas. As a gas, coke, or house fuel, the Pittsburgh coal seems to answer all the demands of the trade.

With but few exceptions, the bed is double, consisting of a roof and lower division, separated by a clay slate parting, which varies from 3 inches to 3 feet, and thins sometimes to a mere knife-edge.

In these townships this parting practically separates the poor from the good coal, as the roof coal is nowhere fit to mine.

The *Roof Division* varies exceedingly, both in thickness and quality, and in the number of its slate partings.

It usually carries from a few inches to a foot of bituminous shale on top, though this is more characteristic of the northern part of the field than the southern, where this shale is frequently absent and replaced by a heavy sandstone, which caps the coal-bed. This bituminous shale has a laminated structure and a fracture like cannel coal.

The roof coal varies from a few inches to 8 feet in thickness, with generally a greater thickness in the north. Ordinarily it consists of two benches, separated by clay; but this structure is by no means typical, for it occasionally shows but a single bench, and more frequently a dozen thin slate partings. Owing to this fact, and the large amount of ash necessarily contained, this roof coal is invariably poor and unfit for mining.

The *Lower Division* of the Pittsburgh coal is from 3½ to 9 feet thick, and shows always three persistent slate partings, which divide it into four distinct benches, known as the "Upper or Breast Coal," the "Bearing-in Coal," the "Brick Coal," and the "Lower Bottom Coal."

The "*Breast Coal*" is the main division of the entire bed. It shows usually the best and thickest coal, and is largely relied on for the total output of any one mine.

North of the river it occasionally shows a small parting near the top; but this feature is rare in the southern portion of the district.

The "*Bearing-in*" division shows usually from 2 to 4 inches of soft coal, with a thin slate above and below it, which renders it always distinct except in some few localities where the bed is a block coal and all partings are wanting. This bench is so named from the fact that the coal is used in mining to bear in upon in order to gain a working-face to wedge or blast out other portions of the bed. It always falls into a slack or dust in mining, and consequently forms no part of the coal output.

The "*Brick Coal*" comes next under the Bearing-in. Shows usually through Allegheny county about 12 or 14 inches of coal. It is named from the character of its coal, which, through peculiar cleavage, breaks out in brick-shaped masses. It generally yields a good merchantable coal, but little inferior to the Breast Coal, though occasionally it becomes too impure to take up, and is consequently left as a floor throughout some mines.

The "*Lower Bottom*" forms the lowest bench of this division. It shows most variation in thickness, carries numerous thin layers of clay, is much broken by cleavage, and is generally regarded as utterly worthless in mining. Occasionally, however, 6 or 8 inches of its top coal is mined, wherever the purity of the bed warrants it.

In general, the coal of the Lower Division seems to increase in thickness southwards, just as the Roof Division diminishes in that direction, so that ordinarily a thick lower division means a thin roof coal, and *vice versa.*

Thus, from Brownsville, where the roof is only 4″ and the lower division 9′, the lower division everywhere shows a magnificent bed of coal, rather softer in character than further north, and frequently carrying a massive sandstone roof, or with but a few inches of shale intervening.

In Allegheny county the lower division is from 5 to 5½ feet thick.

The fuel from this division may be classed as a rather brittle, lustrous coal, rich in combustible matter, and con-

taining a varying percentage of sulphur and ash. Consequently we find this bed in one place—the Connellsville basin, east of the Fayette anticlinal — a superior coking coal, rather soft and friable, and splitting up so readily as to render it unfit for transportation as coal. Passing west over the Waynesburg axis into the Irwin-Waynesburg basin, this same bed becomes hard and brittle, and its fuel makes an excellent gas coal. This basin practically embraces the territory to be specially referred to in this report, as will be seen on page 126.

Formerly quite an amount of coke was produced in this district by the Youghiogheny Coal Hollow Co., at Shaner's Station; the Bigley mines at Alpsville Station, B. & O. R. R.; at Armstrong Station; the old Pennsylvania mine above McKeesport; Stine Bros., Neal & Oliver, and Brown's Saltsburg works, and several other mines all the way to Pittsburgh.

Only the slack coal was utilized at these works for coking, the lump coal being shipped for gas making.

All these ovens are abandoned now, and coking may be said to be confined to the Connellsville basin proper, though in a portion of the Greensburg and Irwin basins, near Irwin Station, on the Penna. R. R., excellent coke is made..

Here though, generally only slack is used, the lump coal of the Westmoreland and Pennsylvania Gas Coal Companies being reserved for shipment and gas purposes. The slack from the mines of these two large companies is mostly washed, and is then found to make an excellent coke, low in ash. The entire product of the Pittsburgh Coal-bed south of the Youghiogheny River and west of the Waynesburg axis is at present shipped for gas or steam purposes.

There seems to be no finely defined line of demarkation as between gas, steam, or coking coal, other than the general one just given. Analysis and structure reveal nothing; but practice, the characteristics of the coal and perhaps, sometimes a little prejudice has fixed these limits as they now exist. A peculiar instance of this arbitrary rule is the grading of coals of the various pools along the Mononga-

hela River, and the affixing of varying prices in the markets of the country for their product, which is frequently not warranted by any difference in the coal itself. There certainly is some variation occasionally, and often within narrow limits of area, but no law for this fact has yet been satisfactorily applied.

In the mines of the New York and Cleveland Gas Coal Company—for instance, at Sandy Creek and Plum Creek—both in the same basin and only a few miles apart, there is quite a distinct difference in the character of the coal from the Pittsburgh bed. The Sandy Creek coal is essentially a gas coal, while the Plum Creek coal is low in bituminous matter and is a much stronger steam coal.

It may be well to record the well known cleavage of the Pittsburgh coal-bed, which, when properly taken advantage of in mining, results in the coal falling out in blocks, the size of which is regulated by the length of the slips. This cleavage produces the "butts and faces" of the miners, the former, or "butt cleavage," usually showing bearings of S. 60°–70° E. or N. 60°–70° W., according as one enters the coal from opposite sides of an anticlinal, and these planes having nothing to do with the line of greatest dip. The "faces of the coal" bear N. 20°–30° E. or S. 20°–30° W., and are at right angles to the butts. The butt cleavage is always quite smooth and regular; the faces are rough, broken and uneven. All gangways are run on one or the other of these planes, in order to save the destruction of coal, except when drainage or other necessity demands quartering.

The Barren Measures.

The characteristic features of this series are the accumulation of sandstones and shales and the occurrence of thin and workable coals and limestones.

Nowhere in this district are any of the coal-beds of the Barren Measures variable or significant.

According to Prof. Stevenson, the extreme thickness *exposed* in this district, along the Monongahela at Pittsburgh and near the State line, is about 375 feet, and in by far the

greater part of Greene, Washington, Fayette and Westmoreland counties, these rocks are either partially obscured or else deeply buried under a covering of higher measures.

The top and bottom of the series, respectively, are the *Pittsburgh Coal-bed* and *Mahoning Sandstone*, making an interval near the Virginia line of nearly 425 feet (as shown by oil wells along Dunkard Creek) and increasing towards the north, where, in Beaver county, the whole system is well exposed. A generalized section here, by Prof. I. C. White, is given in Report K, with measurements varying between 464 and 566 feet.

The variations in individual strata often amount to 25 or 30 feet, so that no particular section in any one part of the field would prove a reliable guide for measurement in another district a few miles distant.

All these rocks yield readily to erosion and create an attractively varied topography; but for this very reason the exposures are few and imperfect, and generally produce confusion and error when taken as starting-points for any measurements.

Still, in order to afford some general idea of this series, and to better illustrate its distinguishing features, the following approximate section is reprinted from the Fayette and Westmoreland county report, KK, page 65:

Section of Barren Series.

1.	*Pittsburgh Coal-bed.*	
2.	Fireclay,	3'
3.	Shale,	10'
4.	Limestone,	6'
5.	*Coal-bed,*	1'
6.	Shale	25'
7.	Limestone	3'
8.	Shale,	10'
9.	*Coal-bed,*	1½'
10.	Limestone,	5'
11.	Connellsville sandstone,	60'
12.	Shale,	35'
13.	*Coal-bed,*	1'
14.	Limestone,	4'
15.	Morgantown sandstone,	50'
16.	Clay,	9'
17.	*Barton Coal-bed,*	1

18.	Shale,	80′
19.	Crinoidal limestone,	4′
20.	Shales and clay,	100′
21.	*Coal-bed,*	2′
22.	Shale,	60′
23.	Black Limestone and shale,	4′
24.	Shale and shaly sandstone,	85′
25.	*Coal-bed,*	2′
26.	Shale,	30
27.	Mahoning sandstone.	
	Total,	491½′

No doubt the above section has been compiled and from exposures to the east of the district under consideration; but it illustrates sufficiently the object sought for. Of the above, the limestone beneath the Pittsburgh coal is rarely wanting in this district, but its interval varies from a few inches to 15′. In some portions of the district a limestone is formed almost immediately under the coal and another a short distance below it.

The *Connellsville Sandstone*, so prominent a feature in the section and in the region from whence it derives its name, can hardly be regarded as a persistent member of the series westward—at least as a sandstone. Its interval is generally filled with shale or shaly sandstone along the Monongahela, where it has certainly lost its characteristic features. It is from 50′ to 80′ below the Pittsburgh coal-bed and is particularly well noticed in southern Westmoreland and Fayette counties.

The *Morgantown Sandstone*, the next great sand rock below the Connellsville sandstone, is persistent all through the field, and is particularly prominent along the Monongahela river at Pittsburgh, Saltzburg, McKeesport, Elizabeth and elsewhere, and along the Youghiogheny, within the special territory of this report. It varies with the other members of the series in thickness and character, but may be always looked for at about 150′ beneath the Pittsburgh Coal. This fact, taken in connection with the Crinoidal limestone at 300′ below the same coal, forms the only two safe guides for measurement in the Barren Measures of the Monongahela district; these intervals are easily remembered.

The Morgantown Sandstone received its name from West Virinia, where, at Morgantown, it is extensively used for building purposes. But in many places along the two great rivers south of Pittsburgh, it forms bold cliffs of massive sandstone, creating a marked feature in the river topography, and an excellent guide to the Pittsburgh bed above it in the hill tops.

At various places it is quarried for building purposes, and frequently occurs as a massive, rather coarse-grained-blue-gray rock, from 40 to 50 feet thick.

In some portions of the field it becomes shaly and worn into pot-holes and weathers freely. On the P. McK. & Y. R. R. it has been extensively quarried for ballast. It is by far the most compact rock of the series, and generally maintains this character over large areas.

The *Barton Coal-bed*, No. 17 of the section, has been frequently identified in various portions of Westmoreland and Fayette counties, and can therefore be regarded as quite persistent.

The *Shale*, No. 18 of the section, is no doubt the Birmingham Shale of the Pittsburgh country, which is quite thick all along the river there, and very prominently identified as the cause for the great land slides that frequently trouble that region. This shale shows a thin, laminated structure, and is greatly jointed.

The *Crinoidal Limestone*, No. 19, the Green Fossiliferous Limestone of the old reports, is the next prominent landmark in the geology of the Barren Measures, though more from its distinctive and peculiar characteristics than from its thickness. Indeed it is rarely over three or four feet thick, and its name is given from the large numbers of crinoidal stems or plates that always accompany it. Its old name of Green Fossiliferous Limestone describes its features well, for it is a dark, greenish-gray rock, with a harsh uneven fracture, and filled with its peculiar fossils. But the name of Crinoidal limestone has taken such a firm hold in the region among those acquainted with it, that it is doubtful whether the former name will ever be used again. It stands alone as a distinct rock in the series, and is con-

sequently a valuable guide for measurement. It can be well seen from Pittsburgh to a short distance above McKeesport along both rivers, and everywhere preserves its typical features, except along the Panhandle R. R. between Pittsburgh and Sheridan Station, where it is accompanied with black shale, is occasionally quite thick, and shows a dull white or gray color.

Directly beneath this limestone there is frequently observed a small but persistent coal-bed. It is of no significance except as an additional means of identification.

The underlying rocks down to the Mahoning sandstone are of little importance, being mostly shales or shaly sandstones, which vary greatly and abruptly. They are nowhere exposed in this district, and need not, therefore, be referred to now.

It remains now in the next chapter to give such special description of the coal and accompanying measures as were met with in an examination of Lincoln, Forward, and Elizabeth townships, though they represent but a small portion of the field occupied during the season of 1885.

Geology and Coal Developments of Lincoln Township.

This township, the most northern of the three under discussion, is surrounded on three sides by the Monongahela and Youghiogheny Rivers, and has for its southern boundary Wiley's and Logan runs, the former flowing southwest, and entering the Monongahela about ¾ of a mile below Elizabeth; the latter flowing north-east into the Youghiogheny at Boston, creating the ravine familiarly known as *Logan Hollow*. In this township the Pittsburgh Coal lies on the hill tops, owing to the presence of the Peters Creek axis, which cuts the township nearly in two equal parts. From this axis-line north-west, everything dips towards McKeesport at the rate of about 75′ per mile. From the Pittsburgh Coal on the summit to the Monongahela River, there is over 250′ of Barren Measures exposed. The most noticeable feature of this section is the outcrop of the Morgantown Sandstone 20′ to 30′ thick, which here rises well up from the river, and presents a bold escarpment.

At Robbins & Jenkins' mine, nearly opposite Coal Valley, this rock occurs about 130′ beneath the coal, and is about 25′ thick. It is greatly weathered into pot-holes and reefs, and carries some shaly bands. A little streak of coal is occasionally seen at its base. The section continued down to the river 125′± more is imperfect, and composed mostly of shales. The rock strata are visibly rising south-east at this point and falling in the opposite direction, the sandstone descending beneath water level about 1½ miles below Robbins & Jenkins' mine, rising again to the north side of the synclinal in the numerous exposures along the P. V. & C. R. R. north of McKeesport. This sandstone is largely quarried near the Harper's Hollow road, where it is gray in color, compact, and massive. It has been used in repairs in Lock No. 4, on the Monongahela, and is about 35′ thick here. Underneath there is about 20′ of variegated shales.

Robbins & Jenkins mine (now W. N. Robbins & Co.) The *Pittsburgh Coal* is opened here at 943′ A. T. and about 225′ above the river. All the coal mined is shipped in barges down the Ohio, no railroad connection having, as yet, been established along the east bank of the Monongahela River. The breast coal is from 3′ to 3′ 4″ thick, with 4″ bearing-in coal, and 1′ of brick coal, with the usual small slate partings between these members. The bottom coal, 1½ feet thick, is not mined, and the main clay, over the breast coal, varies greatly from 6″ to 14.″ In some parts of the mine this clay is a mere knife edge between the breast and roof members. The latter are about 3 feet thick, though no coal over 5 inches is found in them.

The coal seen was rather soft, and in places showed slips of 14 inches.

The main tunnel is driven on the face of the coal, from which butt entries, 8′ wide and 150 yards apart, are driven at right angles. The mine is opened on the single entry system.

A swamp is reported at about 400 yards from the pit mouth, there 17′ deep, which is drained through a butt entry to the Monongahela crop, south-west. The Swamp was noticed in the old front hill levels; but it appears to me that

any face gangway here, driven north-west, would be apt to drain itself, owing to the rapid dip from the axis to the south. All the coal south of the main gangway (about 150 acres) has been mined out, and its drainage had to be provided for by opening out to the river crop—procuring good natural ventilation at the same time.

In 700 yards from the pit mouth, a stationary engine does the hauling from more distant parts of the mine. From the engine landing, horses take the cars to daylight.

These works are connected with the old *Penny mines*, (Lynch & Robinson) opposite McKeesport, on the Youghiogheny. Production here, when active, about 10,000 bushels.

From Robbins' mine, northward, no other openings are made on the Pittsburgh Coal, on the Monongahela face, until at the extreme point of the hill, south of Reynolds, at the old *Hunter mine*, about 940′ A. T. No coal has been run out of here for over 40 years. It was never largely worked.

The crop of the Pittsburgh bed here returns along the Youghiogheny River face of the hill, crossing the hill road at 946′ A. T., and opened at the *Edmunson mine*, about ⅞ of a mile from the junction of the two rivers, and 956′ A. T. This old mine has long been worked out and abandoned.

Miller's Pit, on the public road, was being robbed of some old pillars, but it was not examined.

Lynch & Robinson (formerly Penny Mines) 1 mile from the river mouth, are next south along this crop, at 964′ A. T. and 218′ above the P. McK. & Y. R. R. track. A massive sandstone (Morgantown) is quarried in the run heading up to the mine; 25′ thick at about 10′ or 15′ above the railroad track level. The mine was idle when visited. A single entry system of mining was pursued here, the butt entries being carried through the hill to the crop.

The section in the main tunnel is very similar to that already given at Robbins' mine, with which, as before mentioned, it is connected. The roof coal, however, shows a good 4′ a lower division of coal and slate 2′ thick, separated

by a foot of clay from the upper division 13 inches thick, slaty coal as well.

Immediately south of this mine the hills recede from the river front, and, of course, carry the Pittsburgh Coal back, the erosion being hastened by the waters of a good-sized stream. On a south fork of this stream and close to the public road is

McClure's Country pit, at 998′ A. T. The coal looks bright and clean here. Between this and the south crop there is quite a narrow ridge of Upper Productive Measures, the two crops coming close together near to the road forks at 1108′ A. T.

South, along the ridge road, the first small summit shows smut of the *Redstone Bed* at about 1135′, with the Pittsburgh Coal cropping on the south side at 1060′ A. T. Southeast of this there is a narrow band of Barren Measures cutting out the coal, beyond which coal again takes in at the *Phillips' pit* at 1088′, still rising south east. The coal has about 50′ of cover here, and the hill only contains a few acres. In the rear of this pit the last crop occurs at 1108′ A. T., just north of the Jenny Lind school-house.

Between this and the Calhoun and Crossland coal patches, the axis passes, probably not far from the "Four Forks" in the road. Its passage is marked as elsewhere to the north east by Barren Measure geology, and deeply eroded, but beautifully rounded topography. Of all the Barren Measure rocks in the township the *Morgantown Sandstone* is alone of any consequence or persistence. It is exposed for a considerable distance along both rivers, and is largely quarried for building purposes, quite extensively at the quarry at Sidney Station, of the P., McK. & Y. R. R. It was largely used in the construction of bridge abutments on this road and stands the weather excellently; also for ballast material. The Productive Measures, above the Pittsburgh Coal, north of the axis, are exposed up to the Great Limestone, 160′ above the coal. The lower division of this limestone is quarried and burned on the summit east of the Pleasant Valley school-house in the Edmunson quarry. The stone is reported as making an excellent lime.

The *Redstone Coal* is worthless and slaty here, and is 60′ above the Pittsburgh, and the *Sewickley Coal* horizon was not noticed.

On the south side of the anticlinal there is an area underlaid by the Upper Productive Measures nearly equal to that on the north side of the axis. The Pittsburgh Coal descends south-east at a rate of about 75 feet per mile toward the streams forming the southern boundary. Two outlying coal patches, close to the axis, occur between branches of Dead Man's Hollow and Harper's Hollow, named respectively *Keyes and Calhoun Coal*, about 5 acres, at 1108′ A. T.; and the *Crossland Coal*, about 3 acres, at 1098′ A. T. Neither patch has much cover (about 30′) and both are only mined for local use.

Gumbert, Hewey & Co. is the only firm mining the main body of the Pittsburgh Coal south to Wiley's Run. Their opening on the river is known as the *Bellevue* mine (1050′± A. T.) just opposite Blair Station on the P. V. & C. R. R The gangways are driven over a mile to the crop in a branch of Logan's Hollow; they come out of the west hill at 1009′ A. T.; cross the public road at grade, and pass under Kilgore's house.

Most of the butt entries are driven to the outcrop, thus providing natural ventilation. The cars run into the mine by gravity, owing to the south-east dip, and a stationary engine is located between the two hills to haul the loaded cars from the back-hill workings. A section of the bed here shows:

Roof division,		3′ 9″
Carbonaceous shale,	4″	
Coal,	7″	
Clay,	10′	
Coal and partings,	2. 0	
Main clay parting,		8″
Lower division,		6′ 0
Breast *coal,*	3′. 4′	
Bearing-in *coal,*	4″	
Brick *coal,*	1. 0	
Lower Bottom *coal,*	1. 4	

This mine uses a wire-rope system of haulage. I hope to elaborate the various modifications of this system in the final report.

A combination of the tail rope and engine plane systems has been adopted here for conveying the coal, by means of one engine, from the workings to the river tipple. The tail rope plane is the same as the engine plane, worked in both directions with two ropes. One rope, called the "main rope," is used for drawing the set of full cars outward; the other, the "tail rope," is used for taking back the empty cars, which on a level or undulating road could not be returned by gravity. From the pit mouth out to the check-house there is a fall of 1½′ in 100′, and from the same point, in the opposite direction, to a parting inside the mine, the fall is reversed at a rate of 7′ in 100′. Both rope drums are on the same shaft, driven by a double-acting engine with two 14×24 inch cylinders. The tail rope runs from the drum around a return wheel, placed about 200′ inside the pit and under the rails, and thence to the front car of an empty train at the check-house. Whilst the train runs past the drum the main rope is hitched to the rear car. When the train arrives near the return wheel within the mine, as mentioned above, the tail rope is dropped. The train from this point descends by gravity, carrying the main rope with it to whatever parting is desired. On the return trip of the full train, the tail rope is again taken up where it was dropped and attached to the last car. Once outside the pit, the engine rope is dropped, the cars running by gravity to the starting point, when the tail rope is attached to another set of empty cars and the trip repeated. A full set is 40 cars makes the round trip in a half hour.

Along Wiley's run the Pittsburgh Coal is opened in several country pits. The north branches of the stream carry the coal well up to their heads, owing to the rapid rise in that direction. For a similar reason, the south branches show but little coal.

At Boyd's opening the roof shows but one layer of coal, 2′ 6″ thick, and at Peter Wedell's pit, 980′ A. T., north-east of the Hill school-house, the coal is again opened. The coal sections are quite similar all through this region.

Elizabeth Township.

This township adjoins Lincoln on the south, having the Youghiogheny River for its eastern boundary from Boston to Pollock's Run, opposite Amiesville; the Westmoreland county line on the south, and the turnpike road running south from Elizabeth on the west. Its northern boundary has already been described. The general structural features have also been referred to.

The township practically comprises the double Waynesburg synclinal basin between the Waynesburg and Peters creek (Roaring run) axes, the former barely touching the south-east corner of the township, between Douglass and West Newton, and the latter lying entirely without and to the north of its boundary. Owing to this structure, the area of Upper Productive Measures is much larger here than in Lincoln, the Pittsburgh Coal-bed, in a general way, sinking from the north to the south, and being under water level through seven eighths of the township.

The section of rocks exposed in this township extends from about 150′ below to 275′ above the Pittsburgh Coal, or from the Morgantown Sandstone to the Uniontown Coal.

Cornell & Werling mine (W. H. Brown & Son) is the most prominent and extensive opening in the Pittsburgh Coal along its northern outcrop. The pit mouth is 989′ A. T., located at the head of the east fork of Logan's Hollow, south of Boston, and about 3¾ miles above the mouth of the Youghiogheny river. The mine is not a very old one, having been opened in '65 by Duncan, Cornell & Werling, from whom it takes its name.

The opening is some distance from the river (probably one mile) where the coal is screened into its several sizes for river shipment. The former proprietors sent the entire product of their mine, some 20,000 bushels of lump, nut, and washed slack, to Cincinnati, for gas purposes.

In this mine is one of the best examples of single-entry mining in the district. The main entry is quartered, driven S. 14° E., about one mile to a rear crop in Wild Cat Hollow, and falls with the coal in that direction 94 feet to 895′ A.

T. Crossing the ravine, here about 150 yards wide, it continues into the second hill at a still lower elevation, and will no doubt continue to fall to the first sub-division of the Waynesburg synclinal, nearly one and one half miles further.

The face entries are, of course, laid at an angle to the main gangway, about S. 23° W. and 8′ wide, and 150 yards apart, from which the butt entries are driven S. 65° E. through the field of coal. By this means all the coal in the river front will be drawn into the main entry, and through it to the Wild Cat Hollow. Between entries or rooms is thirty feet. The rooms start from an entry 6′ wide, and in 21 feet they widen to 24′, thus leaving an entry pillar of coal 24′×21′.

The feature of room-driving is a little peculiar, opening out 9′ on *each* side of the six-foot entry. This plan is said to work well. The rooms are carried in 75 yards, with 6′ of coal between them at the entries, thinning down almost to nothing when the two sets of rooms meet. The pillars on each side of the main entry are 15′ thick. Ventilation is obtained from a furnace located in one of the old O'Neil mine gangways.

An average section of the coal here shows:

Carbonaceous shale,		2′ +
Roof division,		4′ 2
Coal,	1′ 0″	
Clay,	9″	
Coal and slate partings,	2′ 5″	
Main clay parting,		0′ 8″
Lower Division,		5′ 9″
Breast *Coal*,	3′ 4″	
Bearing-in *Coal*,	4″	
Brick *Coal*,	1′ 2″	
Lower bottom Coal,	11″	

The lower bottom coal is frequently very clean in this mine and is occasionally taken up. Horsebacks are met with between the first and second roof members. There is also a small swamp in the first hill about 400 yards from pit mouth. The following section shows beyond a clay horseback:

7. Clay,	0′ 8″
6. Coal (block),	0′ 3″
5. Clay,	0′ 3″

4. Coal,	1′ 2″
3. Clay,	0′ 3″
2. Coal,	1′ 2″
1. Main clay parting,	0′ 7″

Above the upper clay No. 7 is coal about 12″ to 14″ thick, and then about eight inches of clay, and above that ferriferous (?) clay limestone; then carbonaceous shale and sandstone roof. All the roof coal is dirty and worthless.

In some parts of the mine the main clay shows double, becoming about 2½′ thick and carrying 3″ of coal in the centre.

An extensive wire rope plant for haulage is in operation here, which is one of the oldest of the kind in the country.

The system adopted here is the "engine plane" the simplest of all systems where circumstances permit its use. It requires only a single rope the length of the plane and the power of the engine only half the time. But while it can be adopted on roads with curves and variable grades, the *fall must be in one direction* and of sufficient inclination to enable a full set of empty cars to return to the workings *by gravity*, dragging the rope behind them. These conditions prevail in this instance.

The system consists of two engine planes, one for lowering the coal from the pit mouth to the river tipple; the other for transporting the coal from within the pit to the mine check-house. The former is something over a mile long, with several sharp curves made necessary by the sinuosities of Logan's Hollow; the latter is about a mile long, with a falling grade of 3¾ per cent. Each plane has its own engine, located near the pit mouth. That for the inside haulage has a pair of 10″ cylinders, 24″ stroke, 10′ wheel, and 5′ drum. The incline engines are of larger size, 12″×24″, with an 8′ drum. Both engines do service at the same time, so that each rope receives and dispatches the set of cars just raised by the other rope. For the outside plane, a ⅞ inch steel rope is used; the inside rope is 1⅛″, consisting of 6 strands of 7 wires each, and a center strand of 7 wires, making in all 49 wires.

A trip consists of about 35 cars, each holding 25 bushels of screened coal. They are brought from the inner parting,

at a speed of 12 miles per hour, to a switch just outside the pit mouth, where the rope is knocked off, the cars taking the left hand and lower track and descending by their own momentum to the head of the river incline. Here the rope of the river engine is hitched on to the *tail end* of the train, which descends to the tipple by gravity. No time whatever is lost in these transfers. This rope is then transferred to the head of an empty train waiting at the tipple, and returns this train to the head of the incline. The empties are here switched off, without loss of motion, to the upper right hand track and their momentum is sufficient, with the down grade, to carry them into the mine, dragging the pit rope after them.

More than ordinary care is taken of these ropes. They receive a coating of pine tar periodically and the rollers are oiled every other day. The latter have a diameter of 8″ and are set 20′ apart. For the curves, cast-iron sheaves, of 12″ diameter, set between the two rails at a slight angle are generally used.

The rope attachment consists of a goose-neck socket, 14″ long, riveted with three ⅝″ rivets, and coupled to a chain 10′ long, with swivel and clevis at the other end.

In descending the outer incline, the coupling chain is led under the last car and hitched to the pulling bar of the next to last car, for the purpose of holding it down and making the rope drop into the guiding sheaves at the curves.

The car-coupling here is rigid. In addition to it, there are two safety chains attached to the cars.

All the larger mines of the district are gradually adopting some system of wire rope haulage, and it can be safely said that owing to the structure of the bed and the frequent necessity of opening it on the dip, in no other region can it be applied with better advantage or with more justification.

The *O'Neill mine*, 999′ A. T., is at the head of the main branch of Logan's Hollow, about one mile south-west. This property is now owned by W. H. Brown & Sons, who operate it in conjunction with their Cornell and Werling mine. The pit mouth is about 1½ miles from the river, and the main gangway enters fully 10′ below the Pittsburgh

Coal-bed, by which a north drainage into the Youghiogheny was obtained for some of the front coal. The workings extend mainly south-west, and over on to the headwaters of Wiley's run. In the field back of Wedell's B. S. S. there is a pump shaft from which the water of the mine, naturally collecting in this direction, is pumped. The bottom of the Pittsburgh Coal is here 955′, or 40′ below the top of shaft, and 44′ below the pit mouth.

There is quite an acreage of untouched coal on the west side of Wedell's run, which will be run out through the Cornell and Werling gangways since the merging of the two properties.

The mine was closed when visited, and the following section is given in K4, page 200:

Carbonaceous shale.	
Roof division,	5′±
Main clay parting,	from 0″ to 4′ 0″
Lower division. Breast *Coal*,	3′ 3″
Parting,	¼″
Bearing-in *Coal*,	3¼″
Parting,	¼″
Brick *Coal*,	11″
Parting,	¼″
Lower bottom *Coal*,	1′ 4″
Under-clay.	

"The main over-clay is absent in a large portion of the mine, and in other places it varies from six inches to four feet in thickness."

South-west along Wiley's run, back of the village of Lovedale, is the *Lovedale mine*, (John A. Wood & Son,) at 953′ A. T.

The pit mouth is located high in the hill, very nearly a mile from the Monongahela River. There is a plane from the check house to the foot of the hill, where the loaded cars are taken in trains of 20 to 25 cars by a locomotive to the river tipple. The Pittsburgh Coal at this mine is about 235′ above Pool No. 2. All the country between here and the river is too low to catch the coal-bed. The coal at the Lovedale pit dips rapidly south-west into the Waynesburg synclinal, the first sub-division of which is about 2,500 yards from the outcrop.

From the pit mouth to where the coal goes under cover at the head of the south fork of Wiley's run is about 1,200 yards. It is opened here at the old *Morton pit* at 908′ A. T., or 45′ below the main opening. This is at the rate of about 75′ per mile, elsewhere noted. The main entry is driven S. 50° E. for 700 yards, and from there S. 35° E. for about 750 yards, which is likewise the direction of a "swamp" developed here. The main gangway at this point is about as far south-east as the Morton pit, but about 200 yards E. N. E. of it. The elevation here is about 850′, or 58′ lower than the crop at the Morton pit. This swamp is reported as 100′ deep and 700 yards in width. Its direction, transverse to the general basin of the coal, is peculiar, and if it shall be found to extend further south-east, beyond the south property line of John A. Wood & Son, it may have some bearing upon the noticeable difference in elevation (22′) in the coal on the north and south sides of Douglass run, 2½ miles to the south-east.

This mine is seriously troubled throughout. In an entry east of the swamp there is a bad roll in the under clay bearing north and south through the mine, which has faulted the coal about two feet. The clay swells and lifts the coal along one side of the fault and cuts away some coal on the other side (KK, 377.) Along this line of fault the coal is highly polished.

Clay veins, *spars*, and *soot veins* are met with frequently, but more to the south of the main gangway than to the north, the latter rendering the coal somewhat soft.

The carbonaceous shale overlying the roof coal is likewise generally thin throughout the mine and frequently absent. Some gas is likewise reported, especially in the entries. Ventilation is secured by a furnace in the north part of the mine and by the exhaust steam from the pumps. In spite of the many irregularities of the bed here, the general product bears shipping well, and has a high reputation.

The mine is worked under both the double and single entry systems.

The same method for hauling the coal is used here as already described at Gumbert & Huly's works. The great

difference of elevation, caused by the swamp in the main entry, provides for the rapid return of the empty cars by gravity.

A section of the coal bed here gave:

Roof division.			
Carbonaceous shale,		4″	4′ 6″
Coal,		2″	
Shale,		4″	
Coal,		10″	
Clay,	1′	[illegible]″	
Coal,	1′	6″	
Main clay parting,			10″
Lower division.			
Breast *Coal,*	8′	0″	5′ 5″
Bearing-in *Coal,*		8″	
Brick *Coal,*	1′		
Lower bottom *Coal,*	1′	2″	

In the "swamp" entry all the members are thicker. The lower division shows:

Over-clay,	1′	0″
Breast *Coal,*	8′	9″
Bearing-in *Coal,*		6″
Brick *Coal,*	1	2″
Bottom *Coal,*	1′	8″

There is about 1 foot of clay between the coal and underlying limestone. Above the Morton pit, the *Redstone Coal* was opened by Mr. Wycoff. The opening is abandoned, and the coal was from 3 to 4 feet thick.

Between Wiley's run and Falling Timber run, entering the river at Elizabeth, the coal is not opened.

The divide is narrow and the coal high all through the property of Isaac Wycoff's heirs. After heading up a branch stream, nearly to the West Bay line, the *Pittsburgh Coal* finally goes under water level on the main stream along the turnpike road near the village of Hilldale, at Horner & Roberts' pit—to be described presently. It is opened on the Elizabeth township side of the road, just opposite the village hotel, at 887′, and 50′ above it, along the road, the *Redstone Coal*, about 4′ thick, shows above Van Kirk's at 937′ A. T. The main road rises to the south-east to a summit (1092′) at the cross-roads below the Round Hill church. This is about the center of the Waynesburg synclinal and

the highest measures in these three townships are exhibited in this vicinity. The country to the north-east, in the neighborhood of Harmony school-house, takes in the *Waynesburg Coal-bed* of the Upper Productive Measures, 350′ above the Pittsburgh Coal, and with a considerable concealed section above this.

The Round Hill church is on the upper or Uniontown division of the Great Limestone, 12′ to 14′ thick, with the *Uniontown Coal* above it, while the road intersection, noted at 1092′, about 40′ below the church, is in the lower division. This limestone must be quite thick, (80′ to 100′,) and its presence is readily seen in the beautiful farms of the Pierce or Piers family, lying further to the south-east, along Pierce's Fork of Howell's Creek.

Beneath the limestone, the horizon of the *Sewickley Coal* is marked with about one foot of carbonaceous matter. Beneath is sandstone and sandy shales for 25 feet, and then the *Fishpot limestone*, about 10′ thick. Below this, sandy shales again occur to the *Redstone Coal*, about four feet thick. The coal is slaty and evidently worthless, and lies about 60′ above the Pittsburgh Coal, which is first seen on the stream at about 800′ A. T., about 200 yards west of the B. S. S. As compared with the opening on the west side of the summit at the village of Hilldale, the coal is here 87′ lower. This opening, however, should evidently be compared to the crop at the Lovedale pit, from which it lies about S. 40° E., along the line of dip. Here we find a difference of 153′ in about 3½ miles. But in the first 1500 yards from Lovedale the coal falls 108′ along the swamp entry, and measured outside along the crop the face is 45′ in 1200 yards. Even at this lesser rate the coal at the B. S. S., on Howell's run, would stand at fully 100′ beneath its present elevation—were the dip uniform. From developments along the northern crop, however, there is every reason to believe this dip is regular for the first mile and a half south-east from Lovedale, *south-east* of which point the coal must rise over the subordinate anticlinal dividing this basin, in order to outcrop again at the B. S. S. at 800′ A. T. And this point cannot be far from the central line of the

trough of the southern sub-division of the basin. For *south* of Douglass Hollow, which is made up of the joint streams of Howell's run and Pierce's fork, the effect of the Waynesburg axis is evidenced in the south-east rise of the coal towards Pollock's run. The rise is slight, owing to the feebleness of the anticlinal here, which is bent aside on the Youghiogheny towards Sewickley creek, in Westmoreland county. Accordingly, after rising along the Youghiogheny, from 819′ A. T., at the Pacific mine, to 838′ A. T., at the Meadow pit, 4200′ below the mouth of Pollock's run, the Pittsburgh bed falls to 833′ A. T. at 500′ below the run; to 761′ A. T. at the Kreps pit, just across the county line, opposite Sewickley station, B. & O. R. R.; to 707′ A. T., at the West Newton Coal Co.'s shaft, about half a mile north of the west entrance to the river bridge, until finally sinking into the bottom of the Lisbon basin at Port Royal, at about 650′ A. T.

As yet comparatively little development has been made in the south-east corner of Elizabeth township—at least the present developments have not yet been extended far enough to warrant definite conclusions as to the form of this interesting basin.

Messrs. James H. Hopkins and W. G. Howell have each a very large territory of coal land here, the balance being held in small blocks by their respective surface owners. The Pittsburgh Coal nowhere crops on Mr. Howell's lands, being entirely under cover. Its natural opening would be, of course, through the trough of the Waynesburg Basin, by a connection along Howell's creek.

Along the eastern border line of Elizabeth township the Pittsburgh bed is everywhere above water level, neither of the sub-divisions of the Waynesburg trough being sufficiently deep to carry the coal below the Youghiogheny River. Its crop line, however, continually approaches the river bank from the north southward, and so feeble is the anticlinal roll between the two sub-basins in this part of the field, that from Buena Vista to the Westmoreland county line the coal elevations vary within 30 feet.

Slack-water navigation formerly extended through all this

territory, and many abandoned pits give evidence of the important contribution these mines furnished to the lower Ohio market. Slack-water at present extends only to Boston, but the construction of the Pittsburgh, McKeesport & Youghiogheny branch of the P. & L. E. R. R. from Pittsburgh, along the west branch of the Youghiogheny to New Haven (Connellsville) has again thrown open this region to the railroad trade, at least, and several important openings are of comparatively recent date. While, therefore, development here has not advanced as rapidly as elsewhere, the recent openings have made use of the experience of others, and attest in their general arrangement an intention to mine coal well and cheaply. Nowhere between this point and Pittsburgh does the great commercial bed of the region reach the same favorable relation to water and railroad levels. The inclines are short and grades favorable, the coal acreage comparatively compact and regular, and with the high reputation of the "Youghiogheny Gas Coal" already established, this section seems to be exceptionally favored.

At the great bend between Boston and Green Oak, the coal is a mile from the river; the front hills are low, and made up of about 250′–300′ of the Barren Measures, with characteristic undulated and rounded topography; the section is imperfect. In Bunker Hill the coal is about 1,000′ A. T. Taken in order southward, the first opening is the old *Eagle Nest mine*, (Green Oak mines,) whose pit mouth is 232′ above the P., McK. &. Y. R. R. track, or about 988′ A. T.

The Eagle Nest mine is nearly worked out, some few pillar-stumps still remaining, and the incline is fast falling to decay. Single entry system prevails here. The main entry is opened on the face of the coal. The south rooms are all abandoned, and the present work is confined to the pillars lying to the north of the main gangway. The coal is very dusty. The breast coal is about 3′ 6″ and main over-clay 9″.

Further south along the crop two other abandoned openings have been made in the Pittsburgh Coal on either side of a small ravine at the *McQuiston* and *Rupert pits*, both at about 900′ A. T. In Duncan's Hollow, south of the sta-

tion of that name, two more abandoned openings occur at 862′, beyond which the Pittsburgh bed was opened at *Cou'-terville pit*, and is mined at *Dravo's* country pit at 847′.

The coal is clean and bright here, though only used for local purposes. Just below Duncan Station, on the P., McK. & Y. R. R., there is a curious instance of false bedding in the Barren Measures, about 100′ below the Pittsburgh Coal.

Just above the railroad the following section is exhibited in which the disturbance occurs:

Sandy shale,	12′
Sandstone—with some little shale,	8′
Black shale—with coal streaks,	8′
Shale,	2′
Flinty limestone to railroad	8′

The sandstone layer completely cuts out the underlying measure and curves over on to the track, suggesting a repetition of the conditions prevailing at Temperanceville, in the high bluff along the Panhandle road below Pittsburgh.

This same disturbance repeats itself further north for 100 yards, the rocks of the above series being often tilted up to an angle of 40° by "horsebacks" and "wedges" of sandstone, which do not seem to disturb the overlying shale rocks in the least. The measures all rise rapidly northwest down stream, carrying these rocks into the hills where they are covered up. North-east, along the point and just opposite Dravo's station, the Lake Shore Gas Coal Co. are operating at the old *Ciera mine* at 808′ A. T. This mine was formerly quite actively worked for the river trade. But until quite recently the works were abandoned for over fifteen years. The south-east dip of the rocks has carried the Barren Measures pretty well under the railroad, the Pittsburgh Coal here being only about 45′ above the track. The present opening is designed for the railroad trade entirely, and is about 1450′ south of the old pit, which will open up almost entirely new territory. The mine is opened on single entry system, the main entry being quartered to the south-west and in 700 yards. The butt entry from the pit mouth is driven to the crop in a ravine back of the river hill, thus securing ventilation. The drainage is toward the

river. About thirty rooms have been turned. The coal here shows a lower division of Breast *coal*, 3′ 6″; Bearing-in coal, 0.4″; Brick coal, 1′ to 1′ 5″; Slate, ¼″; Lower bottom, 12″—16″. Both breast and brick coal are mined on the south side of this hill. Two abandoned pits are located just at Stringtown, known as the *Stringtown* and *Charleston* mines, both at about 800′ A. T., and about one third of a mile apart.

The former was worked for about five years prior to 1861, and mined about thirty acres of coal; the latter for about seven years until 1865. Both are small and long since abandoned. They drain south-east into the river, which is here flowing nearly into the trough of the northern subdivision of the Waynesburg Basin. The centre line may be said to pass approximately through the workings of the *South-west Gas Coal Company mine*, whose pit mouth is at 810′ A. T. This company is working the Pittsburgh bed in the A. M. Bell property, which is practically bounded on the north by a branch of Wild Cat Hollow at Buena Vista, and on the south by a ravine and the W. L. Scott coal.

It may be remarked here that the almost universal north-east rise of all the coal has been temporarily interrupted here, for north-east along the river and across to Westmoreland county the coal levels decline, as will be seen on inspecting the elevations of the Pittsburgh bed around Shaner's and Guffey's Station on the B. & O. R. R. This is indicated in the detailed map showing the contour lines of the floor of the Pittsburgh Coal-bed.

The South-west Gas Coal Co.'s mine is opened on the single entry system, which, indeed, prevails to a great extent through this region.

The ravine of Wild Cat run carries the Pittsburgh Coal well up to the heads of its branches, owing to the rapid N. W. rise of the measures to the anticlinal.

The coal is opened in several pits north-west of Buena Vista. The Cornell & Werling rear pit is the one nearest the head of the main stream, the coal going under water level on the public road a hundred yards north-west, with the *Redstone Coal* above it 50′-60′, and about 3 feet thick. The limestone underlying the coal is very well exposed all

through this ravine and in the run, and it is about 10′–12′ thick. About 1,200 yards down stream, on the north side of the public road, opposite Patterson's, the coal is opened at *J. R. Henderson's upper pit*, 59′ below the Brown tunnel coal, at 836′ A. T. The coal here shows :

Roof division.		
Carbonaceous shale,	1′ 0″	4′ 10″
Coal,	1′ 0″	
Clay,	0′ 10″	
Coal,	2′ 0″	
Main clay parting,		10″
Lower division.		
Breast *Coal,*	3′ 1″	5′ 6″
Bearing-in *Coal,*	0′ 3″	
Brick *Coal,*	1′ 0″	
Lower bottom *Coal,*	1′ 2″	

The roof division coal is very slaty, with numerous thin partings.

Opposite Daggart's Hollow the coal is again opened at *Henderson's Lower pit*, near the outskirts of Buena Vista, at 816′ A. T. The bed section is well shown here, as follows :

Carbonaceous shale,	1′ 0″
Coal,	10″
Clay slate,	11″
Coal,	1′ 11″
Main clay parting,	0′ 11″
Breast *Coal,*	3′ 0″
Bearing-in *Coal,*	5″
Brick *Coal,*	1′ 0″
Lower Bottom *Coal,*	1′ 0″

South-west from here and up Daggart's Hollow, the first opening is *Daggart's Lower pit*, at 816′ A. T.

Daggart's Upper pit is opened 200 yards up the hollow from the last at 821′, and close to the last appearance of the coal.

Eicher's pit, on the north side of the road, is at 816′.

Eicher's pit, on the south side of the road, is at 821′.

The appearance of the coal in all these openings is very similar to that on Howell's Run further south.

In report KK, p. 375, the following reference to one of them appears :

"A curious clay vein occurs near the mouth, which faults

the coal nearly 10″. At the base is a broad roll of the under-clay, but above it suddenly narrows and passes almost vertically through the coal, throwing off a branch on each side as it enters the main clay, and again as it goes through the clay of the roof division. It spreads out for a little way on the top of the bed, but does not affect the overlying shale."

South along the river from the ravine, cutting off the South-west Gas Coal Company's tract, a large area of the Pittsburgh Coal is owned by W. L. Scott, of Erie, Penna. The position of this body of coal, which is practically compact, is shown on the map, and comprises about 1,600 ± acres.*

Here are located the Ocean mines, Nos. 4, 3, and 2, the two former in a little ravine 600 yards north of the village of Industry, and through which a siding is laid from the P., McK. & Y. R. R.; the latter, Ocean, No. 2, about 400 yards south from Industry, immediately above the main track, the coal being dumped directly from the screens of the tipple spanning the railroad.

In addition to these two openings, Mr. Scott has a third, *Ocean No. 1*, on the Westmoreland county side, at Scott Haven, where an extensive plant and miner's village exists for the development of these mines. The latter, of course, ships *via* the B. & O. R. R. This mine will be referred to in detail at some future time, lying without the district under discussion.

The pit mouth is about 30′ above Scott Haven, (Moore's Station,) B. & O. R. R., or 793′ A. T., and about 60′ above the river. The coal falls gently to the *north-west*, or down river, into the Waynesburg Basin.

The lower division coal benches are 44″, 4″, 12″, and 12″, respectively, the lower bottom (12″) being pyritous. The output is 600 tons.

Ocean mines, Nos. 3 and 4, have openings on either side of the ravine, at 811′ A. T., the coal being brought to the joint tipple immediately over the P. McK. & Y. R. R. siding.

*Recently the S. W. Gas Coal Company tract, and Bly's Atlantic mine tract, have been purchased by this company, which now controls about 2,000 acres.

The gangways are driven at right angles to the creek, northwards into the South-West Company's tunnel, and southwards into the "north side tunnel" of the No. 2 mine, so that the workings of all three mines are practically connected with each other and with the S. W. Gas Coal Company mine.

Ocean mines, No. 2, (W. L. Scott,) tipple, south of Industry, is directly over the P. McK. & Y. R. R. track, and the pit mouth is only 25 yards from the check-house. The bottom of the Pittsburgh bed is at 807′ A. T., or 45′ above track; but the gangway is laid down in the limestone below the coal, for grade and drainage. The bluff, above the track, which is steep, shows about 35′ of sandstone and shale, and 4′–6′ of limestone, 5′ of shale to the coal. There is about 1′ of under-clay.

A substantial arch of stone masonry is set into the bluff to protect the gangway, which is here double.

At the pit mouth the Lower Division shows the following benches: Breast coal, 44″; Bearing-in, 3″; Brick coal, 10″; Lower Bottom, 15″–20″.

None of these mines could be entered during the summer of 1885, though several attempts were made, and it was only recently (February, 1886,) that an inspection of this mine and the system of drainage was made under the guidance of John Thomas, superintendent. From information obtained through him, it is rendered fairly certain that the suspected sub-division of the Waynesburg synclinal, known to exist on the Monongahela, likewise prevails here on the Youghiogheny, though in the absence of any reliable data the map was constructed to show but one basin in this synclinal.

The main tunnel is driven N. 63° W., about on the butts of the coal, and declines in that direction for 1750′ to the "swamp," where the coal is 14′ lower than at the pit mouth, or 793′ A. T.

The total length of the tunnel February 22, 1886, was about 2400′, or 800 yards, from the pit mouth.

The mine is divided into north and south side workings. The main north side tunnel is driven double, leaving the

main tunnel at a point about 400′ in from the pit mouth, and keeping a general N. 9° W. course, quartering the coal for 2,600′, and then about 1,800′, on a nearly north course, finally entering the main gangway at Ocean mine, No. 3, which is driven S. 27° E. from the little ravine shown on the map. Just at this junction appears to be the divide between the two sub-divisions of the synclinal, as the water runs north-west out of No. 3 pit, south-east towards the furnace and crop, and south-south-east along the north side tunnel towards No. 2.

In the latter tunnel, for the first 1,700 feet, the coal falls about 6″ per 100′, and then becomes generally flat on the way to the No. 3 workings.

From the tunnel to the outcrop S. S. E., several gangways have been driven to take out the front coal, Nos. 1, 4 and 5, 8 and 9, having been driven to daylight.

In the entries on the north side of this tunnel, all of which are double—No. 5, 2 and 3, 6 and 7, 10 and 11—the coal, as far as developed, is generally pretty level.

Butt entry, No. 14 and 15, leaving this tunnel about 2,500 feet from the main tunnel, extends N. 63°-65° W., and is designed to meet the workings of No. 4 mine.

The latter, No. 4 pit, is located on the north side of the ravine, the main gangway entering the hill, coincident with the course of No. 3, or about N. 27° W., the coal practically rising in that direction, though declining at first for a short distance.

From this main tunnel a quarter tunnel has been turned and carried in all 2,200′. For 1,300′ of this distance the coal is pretty level; but, in the next 700′, there is a fall of 18′ into a swamp. The line of swamp lies a little north of this tunnel, crosses it at 2,000′ from the pit mouth, and probably swings around southward to join that developed in No. 2.

South of the main tunnel in No. 2 the workings are designed to join the Atlantic Mines.

A tunnel, No. 1 and 2 south, is driven about S. 41° W., a little off the face from a point on the main tunnel, about 205 yards in from pit mouth.

The coal distinctly rises in it going south-west parallel to

the line of synclinal, here practically in the river. Three double sets of butt entries have been turned North 63° West off of this tunnel about 200 yards apart, and three single entries turned south-east to remove the coal between the tunnel and the outcrop.

No. 2 and 3 butt entry is in over 1,500′ and dips N. W.; so likewise do Nos. 5 and 6 in 1,600′, both advancing towards the same swamp developed in the main tunnel of the mine.

As yet no levels have been kept here, as far as could be learned, though from the position of this group of mines in the basin, they would prove useful in planning new works. The mines are generally worked on double entry, and have been well planned and thoroughly opened up, so that rooms can be readily turned and a production of a thousand tons a day kept up if necessary. No wire rope is used here as yet. The mine is exceedingly dry, for wherever necessary deep drains have been laid to carry the water by gravity to some central point. This will eventually be in the swamp near the main tunnel, from where it will be syphoned out.

A furnace, located near the pit mouth and south of main tunnel, affords excellent draught for the mine. It is 9′ diameter, 30′ long, and with about 52′ of fire surface. A shaft, 8′ diameter and 94′ high, with 25′ additional stack, leads up to surface. Coolers are carried around the sides and tops of furnace, and air is supplied from 2 gangways, 8′ wide and 6′ high, which diverge from in front of the furnace.

Throughout No. 2, spars and clay veins are not infrequent, but they are generally far apart. Several have been met in No. 14 and 15 butt entries.

The coal will average about as follows:

Main clay parting,		10″ to 1
Bony *Coal,*		2″
Breast *Coal,*	3′	4″
Bearing-in *Coal,*		3½″
Brick *Coal,*	1′	0″
Lower Bottom *Coal,*	1′	0″

The brick coal is mined throughout the mine, the Pittsburgh Bed here furnishing about 4′ 4″ of merchantable coal.

The Finney Coal, adjoining the Scott lands on the south, has nowhere been opened. The outcrop of the Pittsburgh

bed, however, is seen continuously in the river bluff, until passing into the Douglass property, it is opened at the *Atlantic mines* at 790′ A. T. A short incline carries this coal to the P. McK. & Y. R. R. track, near the station. The drainage is south-east.

Further west, along the main stream, the coal in a country pit at road level rises to 797′ A. T., going under water level finally on Howell's Run, at 807′ A. T.

In these openings the following structure prevails:

Roof division.		
Coal,	0′ 10″ to 1′ 0″	
Clay,	1′ 0″ to 1′ 2″	3′ 10″ to 4′ 4″
Coal,	2′ 0″ to 2′ 2″	
Main clay parting,		0′ 10″ to 1′ 0″
Lower division.		
Breast *Coal,*	3′ 6″	
Bearing-in *Coal,*	0′ 2″ to 0′ 4″	5′ 6″ to 6′ 0′
Brick *Coal,*	0′ 11″	
Lower Bottom *Coal,*	0′ 11″ to 1′ 2″	

The carbonaceous shale, capping the roof division, is either entirely absent or very thin here, and the roof coal, as elsewhere, is apt to be mixed up with clay and slate bands, rendering it unfit for mining. Some little pyritous slate is also frequently found dividing the "breast coal."

On the south side of the run the coal is very much higher, and the valley must either mark a line of fault or a "swamp"—the latter being the more probable, in the absence of all proof of a fault.

The *Pacific mine*, (Bly) at 819′ A. T., is opened by a face entry, dipping south-west for 500 yards, which is expected to drain at the rear pit mouth, near forks of stream, at 812′ A. T. The coal rises gently to the *south-east*, as already stated, to pass over the end of the Waynesburg axis.

Forward township.

This township has for its boundaries—Elizabeth township on the north and east, the Monongahela River on the west and south, with a small portion of Westmoreland county (Rostraver township) on the south, between the river and the turnpike road. The latter is the common divide between Elizabeth and Forward townships. Its

geology is but a south-eastern prolongation of that of Elizabeth township, except that the general south-west inclination of the measures has buried the Pittsburgh Bed under still more cover in the Waynesburg trough. However, the combined effect of the Peter's Creek axis to the north-west of the township limits, and the erosion of the Monongahela River, has resulted in the uninterrupted exposure of the great coal-bed along the river, from Falling Timber run and Elizabeth on the north, to the Westmoreland county line on the south.

As yet no railroad touches its border lines, and dependent, as it is, therefore, entirely on the river traffic, it is not strange that all its development should have been made along its river crop line.

With the exception of Messrs. Horner & Roberts, H. D. O'Neil and James G. Blaine, the product of this township is classed as Pool No. 3 coal—a necessarily unjust commercial discrimination on account of the identity of the coal-field being developed by all operators here. The same remark might apply to other parts of the Monongahela district, for while there are certainly distinctions to be made as to the First and Fourth Pool coal, it frequently happens that an operator who has his tipple plant in one pool is mining coal three or four miles back from the river in a totally different pool. And yet, his coal is classed in the pool bringing the best price, of course, while his neighbor, working the same coal in adjoining gangways, nevertheless loads his coal a mile or two further up the river, and must submit to a corresponding discrimination in price. Arriving in the Cincinnati or New Orleans markets—side by side—the two boat loads are necessarily similar, but the price paid is not.

Lock No. 3 is located close to the Washington county line, and about two miles south from Elizabeth. Pool elevation 730′ A. T. The geological section in this township extends from about 200′± below to 280′ above the Pittsburgh coal, or from the bottom of the Morgantown SS., in the vicinity of Elizabeth, to the Waynesburg Limestone on the headwaters of Kelley's or Leech run, near the telegraph road.

In KK, p. 379, mention is made of a high hill to the south, no doubt at the headwaters of Perry's Mill (Pangborn's) run, where the horizon of the *Waynesburg coal* was reached without finding the bed exposed.

The *Uniontown Coal* and *Limestone* horizon is reached in several places; on the telegraph road, 1¼ miles south of Elizabeth; on Perry's Mill (Pangborn's) run, and on Leech (Kelley's) run, while the lower division of the great limestone, 60'± thick, is frequently seen all along the river front near the hill-tops, and is especially well seen along the above runs, one to one and a half miles back from the river.

The *Sewickley Coal* was not noticed; but the *Redstone* is opened in several places, and its composition here is very much more favorable than in the other two townships. Above Hayden's mill, on Falling Timber run, this bed is from three to four feet thick, clear coal and with but little sulphur. But the coal carries a high percentage of ash, nearly twice that of the Pittsburgh Bed, and, of course, will never be mined while that bed exists.

The *Redstone Coal* has a similar character along Perry's mill and Leech's run, where, however, it is said to carry more sulphur. It is everywhere from 50 to 60' above the Pittsburgh Coal-bed.

The Pittsburgh Coal Bed.

The first opening in the bed is at the *Horner & Roberts' mine*, 879'A. T., situated at Hilldale, near the forks of Falling Timber run, about two miles from the Monongahela River, at Elizabeth.

A large tract of coal is owned by this company, whose boundaries are shown on the map accompanying this report. In addition to this, the same company own the coal in the S. W. Applegate tract, lying to the north of the main body, where a new opening has been made at 882' A. T.

This opening is in the limestone about 2' under the lower division coal, which is here about 6' thick.

The front coal in the large tract has been pretty well exhausted. The present opening is close to where the Pittsburgh coal disappears under cover on the turnpike. The

dip is to the south-east here, into the first sub-division of the Waynesburg Basin.

The mine is worked by the double-entry system, and the following facts were elicited from an inspection of the company's maps and the mine:

The main entry is driven about S. 23½° W. from the pit mouth for nearly 5,000′ towards the corner of A. & C. Wall and I. Wall's lands (see map) following the general direction of the stream, and dipping continuously all the way.

From a point 350 yards in from the pit mouth the "air and water-course gangway" diverges from the main entry, bearing S. 51° W. for some 3,000′, to within about 500 yards of the A. & C. Wall property line. This entry likewise dips, the coal at its face being over 50′ lower than at the pit mouth. The "swamp entry" has about the same general bearing as the above, leaving the main entry about 400′ further in than the water-course gangway, or at about 500 yards from the pit mouth. The coal at this point is 32′ lower than at the crop, or 847′ A. T.

The swamp entry has a sinuous, irregular course, following the bottom of the swamp as far as developed, though generally parallel to the water-course. This entry is about 2,000′ long, the coal at its face, 1,150 yards from pit mouth, standing at 797′ A. T., or 82′ lower than at the crop.

In the butt entries, bearing north-west and south-east from the swamp entry, the initial rate of rise in the coal is very rapid. The swamp is estimated to be about 300 yards wide and 30′ deep, outside of which limits the dip of the coal-bed is quite regular. All the front coal of this mine has been worked out by the single-entry system, butt entry No. 7, counting in from the pit, being the first double entry driven.

This entry leaves the water-course gangway on a course of about N. 63¼° W., bearing towards the McKinney line, where it meets the air entry, driven in a circuitous course along the property line divide between Horner & Roberts (T. Furgus' tract) and W. Wall's lands. No. 7 entry is 2,900′ long, and rises N. W. at the rate of about 80′ per mile.

Three more butt entries, Nos. 8, 9, and 10, have been driven north-west from the water-course gangway, all showing about the same rate of rise, away from and dip toward the swamp. Entries are likewise driven between the main entry and the swamp entry, No. 9 butt entry being the first double entry on the east side of the swamp. These entries all rise to the south-east so rapidly toward the face workings as to require an engine plane 270′ in the first No. 10 mine to convey coal from the swamp workings.

All the drainage-water possible is conducted to the bottom of a shaft 133′ deep, located near the swamp entry and No. 9 east butt entry, where five steam pumps force the water to daylight.

A section of the measures immediately overlying the Pittsburgh Bed, in this shaft, was kindly furnished by Matthew Creevy, mine superintendent, which shows the following measurements:

Section of Upper Productive Measures in shaft at Horner and Roberts mine, above the Pittsburgh Coal in swamp at entry No. 9.

Surface.		
Loose gravel,	5′	6″
Clay,	6′	0″
Brown limestone,	4′	0″
Brown stone,	2′	6″
Soapstone shale,	12′	6″
Blue limestone,	1′	6″
Brown sandstone,	5′	0″
Soapstone,	5′	5″
Blue sandstone,	3′	6″
Coal, Top Seam, (Redstone *Coal-bed*,)	4′	0″
Soft blue slate,	18′	3″
Black slate,	15′	0″
Cement rock, white,	5′	0″
Light blue sandstone,	8′	6″
Dark brown sandstone,	2′	6″
Brown soapstone,	5′	0″
Gray SS.,	4′	3″
Brown shale,	6′	0″
Sandstone,	3′	6″
Brown shale,	2′	0″
Dark blue slate; good,	5′	6″
Coal,	0′	5″
Soapstone shale,	1′	6″

Top Coal, first bed,	Pittsburgh *Coal-bed*, 10' 5½" in "swamp."	1' 0"
Shale parting,		0' 3"
Top Coal, second bed,		1' 0"
Main clay parting,		0' 11'
Main Coal,		4' 6"
Bearing-in slate *Coal*,		0' 3"
Slate,		0' ¼"
Brick Coal,		1' 0"
Slate,		0' ¼"
Bottom Coal,		1' 6"
Limestone.		
Total,		133' 6"

This section of the Pittsburgh Coal is, as usual, abnormal, by reason of the increase in thickness of all swamp coal. In this mine, the coal is low, a section between entries Nos. 9 and 10 at mouth of tunnel showing:

Coal,	0' 7"
Clay slate,	1' 9"
Coal,	1' 0"
Slate parting,	0 1½"
Coal,	1' 1"
Main clay parting,	0' 11"
Breast Coal,	2' 10"
Bearing-in Coal,	0' 3"
Brick Coal,	1' 0"
Lower Bottom Coal,	1' 1"

Another section of the "swamp" coal, given in Report K^4, p. 128, gives:

Roof coal.		
Overclay,		0' 10"
Lower Division, . . . 7' 4"	*Breast Coal*,	4' 0"
	Parting,	0' ¼"
	Bearing-in Coal,	0' 6"
	Parting,	0' ½"
	Brick Coal,	1' 3"
	Parting,	0' ¼"
	Bottom Coal,	1' 6"
Under-clay.		

The latter shows the usual thickening of the members in the swamps. In the other gangways, the following may be taken as a full general average:

Roof division.		
Carbonaceous shale,	0' 3"	3' 6"
Coal,	0' 4"	
Clay,	0' 11"	
Coal and partings above,	2' 0"	

Main over-clay,			5′ 10″
Lower division.			
Breast Coal,	3′	2″	5′ 10″
Bearing-in Coal,	0′	4″	
Brick Coal,	1′	0″	
Lower Bottom Coal,	1′	4″	

Clay veins were seen in the water-course gangway, between Nos. 7 and 8 entries, running in every direction and sometimes crossing one another. They generally thin out towards the swamp, only 3″ out of 18″ or 20″ in the water-course gangway being prominently seen there. Some are white clay; others a heavy, hard, black spar.

From the pit mouth to the river tipple, the coal is moved over a surface track by locomotives, in trains of 40 to 45 cars. Inside the pit a wire main and tail rope system is in use, the engines for which are located just outside the pit mouth. The main gangway, bearing S. 23½° W., dips regularly from the crop line, and in hauling the loaded cars up from the parting, 350 yards in the entry, the main rope of the tail rope plane is used as a simple engine plane, the empties returning by gravity. The entry, bearing S. 51° W., is nearly level for the first 500 yards. A sheave wheel is placed in the parting under the tracks, and the empty cars are conveyed there, with the tail rope hitched to the front of the train and the main rope to the rear, as usual; and in the return of the full cars, the ordinary method is pursued as already described. This modification saves more rope for the main entry, owing to its steep dip carrying the cars in by gravity. At the meeting point of the two gangways, however, the tail rope is again fastened on to the train—the *next* to last car—and the usual method carried out from there to the check-house. The ropes are of steel, respectively ⅞″ and ⅝″, with seven wires to the strand. The main rope is carried along the gangway, on rollers 18′ to 20′ apart; the tail rope is led over rollers in the roof, which thus keeps it out of the way. At any curves in the gangways, heavier and larger rollers are placed *outside* the track, upright and close together, so as to guide the rope around the curves.

This wire rope is at present laid about as far as No. 8

butt entry, where there is a parting and side track for making up the full train, the sheave wheel being placed upright between two mine posts. The proprietors look forward to an early extension of the system on the east side of the mine, along the main entry to No. 10 butt entry, and are now driving a tunnel above the coal in the swamp, so as to connect the west and east side of the mines by a suitable grade entry before conveying all the back coal out by means of the wire rope system. About 250 acres in all, have been worked out here. An inspection of the map accompanying this report will show the outcrop of the Pittsburgh Coal extending N. W. from this point through the Wall and Applegate lands, until again opened at the

Harvey O'Neill mine, at 941′ A. T., on the river front lying just south of Elizabeth. This is about the highest coal in the township, the dying anticlinal axis lying just across the river from this point. The pit mouth here is 211′ above the river. The plane is some 700 yards long, by which the cars descend to the tipple by gravity, and are hauled back on the simple engine plane system, the stationary engine being located near the pit mouth.

The mine was entirely closed when visited, and no personal inspection was made in consequence.

The bed is reported from 5½′ to 6′ thick in the *lower division*, and dips south-east.

Walker mine (Jas. G. Blaine) lies about ½ mile further south-west, along the river front, and is opened at nearly the same elevation. Mr. Blaine's property has a frontage of about 200 rods along the Monongahela River from Lock No. 3 northward, and is, therefore, rated as Pool No. 2 coal.

There are three tracts owned in fee simple, comprising about seven-eighths of the river front, and extending back to McKinney's fork at Perry's mine (Pangborn's) run, which enters the river just above the lock. But the bulk of the coal lies in the mineral tracts extending south-east from McKinney's fork to the head of the main stream, through the McKinney, Christy, Saddler, Applegate, Caldwell, and Gamble tracts. This mine was also abandoned, and the coal in the front tracts is reported pretty well worked out.

Below the check house to the river there is about 200′ of Barren Measures. By far the most conspicuous member of this group, not only here but elsewhere along the river road south for some distance, is the Connellsville Sandstone and underlying shale, the Morgantown Sandstone sinking beneath the river. The section is composed mostly of shales, the sandstone losing its compactness and massiveness.

The hills are frequently shaly SS. bluffs, exposing 100′ of these measures, along which for some distance south of Elizabeth the public road has been constructed with difficulty.

The *Pittsburgh Bed*, on McKinney's Fork, shows about 3′ of coal in the roof division, and 5½′ in the lower division; but both the "brick" and "lower bottom" members are frequently sulphurous. The following section was given me as the average in the Walker mine workings:

Roof division.		
Carbonaceous shale,	0′ 4″	4′ 11″
Slate,	0′ 9″	
Coal,	0′ 10″	
Slaty coal,	0′ 10″	
Coal,	2′ 2″	
Main over-clay,		0′ 10″
Lower division.		
Breast Coal,	3′ 2″	5′ 6″
Bearing-in Coal,	0′ 4″	
Brick Coal,	1′ 0″	
Lower Bottom Coal,	1′ 0″	

The roof coal is slaty and filled with clay veins; the lower division coal is generally clean and bright.

There are various old country pits on the branches of the streams, but their coal shows little or no variation from the above. The crop extends up the main fork to just beyond the saw mill, at the meeting point of the Blaine, Brown & O'Neill coal. (See map.)

On Leech run (Kelly's) the coal is again opened at the *Wenona mine* (Leechburg) of Wm. Skillen & Co., dipping S. E. The main opening is about ¼ mile from the river, and is reached by a tram road skirting the west bank of the stream until nearly opposite the pit mouth, and there crossing the run by a high and long trestle incline to the pit mouth at 830′ A. T. This mine has been a large producer in the past.

The crop has been opened in several places towards the river, one 840′ A. T., and one at 843′ A. T. From here to the Harvey O'Neill mine is about 2 miles, the coal rising parallel to the trend of the axis 100′ in that distance, or at the rate of 50′ per mile, which is unusual. From Wenona mine south-west to the Old Eagle works is about 2¼ miles, and the total fall is only 60′. At Wenona the breast coal is 3′ 4″, brick coal, 1′ 1″, and the roof division is unusually developed for this section of the country. The full section shows:

Roof division.		
Carbonaceous shale and slate,	0′ 10″	5′ 2″
Coal,	0′ 1″	
Shale,	0′ 8″	
Coal,	0′ 7″	
Clay slate,	0′ 10″	
Coal, with clay veins,	2′ 6″	
Main clay parting,		0′ 10″
Lower division.		
Breast Coal,	3′ 4″	5′ 10″
Bearing-in Coal,	0′ 3″	
Brick Coal,	1′ 1″	
Lower Bottom Coal,	1′ 2″	

The Pittsburgh Coal disappears on Leech run a little over a mile from the river, close to the Horner coal on the P. Lytle farm, and a third of a mile down stream from the West Bend school-house.

One mile west, up the river from the village of Wenona, the *McKnight mine* (O'Neil & Co.) is located, 100′ above the river, or 833′ A. T. The works are entirely abandoned. The coal dips south-east. Eight hundred yards west, a tramroad enters a small ravine to Jones' limestone quarry. One half mile from the river the coal is opened in a couple of country pits, close to the run, at about 780′ A. T. The dip here is also S. E.

Old Eagle mine, located just above the village of Elkhorn, is the next important opening on the Pittsburgh Coal-bed. The several openings here are on the property of W. H. Brown's heirs. The present main entry is 770′ A. T. and 40′ above the river in Pool No. 3—just opposite Courtney Station, P V. & C. R. R. It is 2500 yards south-west of the McKnight mine (see large map).

About 600 yards north-west, the outcrop is again opened on this property at the *Gardner pit*, at 776′ A. T., near Brown's school-house; and south-east 450 yards at the *Moore pit*, 778′ A. T., but now belonging to the Old Eagle works.

This mine was opened about 25 years ago, and owing to its position, right in the axis of the north sub-division of the Waynesburg Basin, its development has presented many interesting features of the characteristic structure of the Pittsburgh Coal when similarly situated in troughs or swamp lines, and illustrates the great irregularity of the floor of this bed.

The mine is worked on the double entry system, two main entries being driven in about 450 yards apart on the outcrop. The first, or *swamp entry*, follows the "swamp" for about 300 yards N. 50°–55° E., there turning N. W. near the air gate between entries 5 and 7, into the present workings, some 1800 yards from the pit mouth. This entry is driven double, with an air course, which is *practically* parallel with the traveling way, with a coal pillar averaging 40′ between them. The swamp has been developed for about 650 yards, 200 yards wide and 30′ deep. It is almost level near the crop line, but there rises north-east along its bearing.

The coal on either side of it dips rapidly *into* the swamp, and the side workings are all led into it. It is proposed finally to drain this swamp by laying pipes into its deepest part and utilizing the engines outside for pumping.

The coal, as usual, is thicker in the swamp than elsewhere. A section in No. 11 entry gave, for the lower division:

Main over-clay,	1′ 3″
Breast Coal,	3′ 3″
Bearing-in Coal,	0′ 8″
Brick Coal,	1′ 7″
Lower Bottom Coal,	0′ 9″

The upper 3″ of the lower bottom coal is very sulphurous. They take down the main clay generally throughout this mine, as it is very weak and soft, and use it for gobbing the empty rooms. These rooms are 33′, centre to centre, turned

off 7′ wide and carried thus for 21′, and then widened to 24′–27′. The rooms are 75 yards long, and have 5′–6′ pillars between, which, however, are pared down constantly as the rooms advance.

The roof division, just where the tunnel leaves the swamp, shows:

Roof division.		
Carbonaceous shale,	2″ +	8′ 9½″
Slate,	¾″	
Coal,	7″	
Slate,	4″	
Coal,	4″	
Slate,	½″	
Coal, bony in top,	5″	
Clay slate,	9½″	
Coal,	1″	
Slate, sulphur,	¼″	
Coal,	8″	
Slate,	1″	
Coal, slaty with sulphur,	6″	
Coal, sooty,	1½″	
Coal,	2″	
Main over-clay.		

The breast, bearing-in, and some of the brick coal is mined here in one bench, 50″ to 58″ thick.

No. 10 entry, driven on *west* side of swamp entry, nearly opposite No. 11, rises and then falls to the "water pit entry," and along the latter, just above No. 10, there is another small "swamp" about 5′ deep. In the next two entries, Nos. 12 and 14, on the west side of the tunnel, the coal is level. Entries 11, 9, 7, and 5, on the *east* side of the main gangway, dip rapidly south-east into the swamp.

No. 3 entry, close to the pit mouth, was driven through the *roof* coal in order to get into the lower division coal on the east side of the swamp, where the coal rises quite as fast eastward. The upper workings here are laid out quite regularly in blocks of 150 square yards.

Another small swamp was met with here, near the extreme east side workings, beyond the second main entry, which is driven perpendicular to the faces of the coal.

A *compressed air locomotive*, which is unique throughout this district, is used instead of wire rope for hauling the

coal cars from the main partings inside the mine to the river tipple.

A photograph of this locomotive is in K[4], page 80, and the following description of it is given there:

"The locomotive consists of two cylinders, each 22 feet in length and 36 inches in diameter, placed on a truck or carriage side by side, which, together with its levers, connections, and other necessary parts, amounts to 27 feet in total length. It is charged by the use of a high and low pressure air engine, run by steam power, stationed near the pit mouth. The amount of pressure used, as indicated by the air guage, is 400 pounds per square inch. The locomotive makes a round trip in from 7 to 10 minutes, which reduces the pressure to about 250 pounds."

Of course, the engine is only used for the main gangways, the cars from the various entries and rooms being collected at some parting. The engine is under perfect control, and I should judge it would be especially serviceable in crooked gangways and in the mines of the upper pools, where the lower division (commercial) coal becomes 8′ and 9′ thick. At Old Eagle a good deal of the roof coal must be taken down to accommodate the passage of the locomotive, which requires an entry about 8′ wide and 6′ high. Mules are used to collect the cars at the parting and distribute the empties to the working faces. The coal is faulted in entry No. 5, the fault line being in and parallel to the swamp axis, and throwing down the swamp coal about 5′, it extends for some distance N. E., being noticed in other entries. A second "fault" further west, near the edge of the swamp, of similar character and effect, was reported, which, however, I did not see, owing to the water in the swamp. Mr. J. E. Jones, superintendent, extended every courtesy during the examination of the mine.

He reports the mine as being generally free from firedamp and well ventilated by furnace and natural air. The furnace is located near the old pit mouth, to the east of the main swamp gangway, and further up the river. The area of coal mined is over 100 acres, and the present output is to be considerably increased by the introduction of coal

cutting machinery, which had not had a trial at the time of my visit. Air will be furnished these machines from the same engines that supply the locomotive.

A section of the coal in the east or upper workings, in entry No. 3 and away from all swamps, gave:

Roof division,	4' 6"
Main over-clay,	0' 10"
Breast Coal,	8' 1"
Bearing-in Coal,	0' 3"
Brick Coal,	1' 3"
Lower Bottom Coal,	1' 4"

The presence of this large swamp in this mine, and its general bearing, suggests its connection with those found in the developments to the north-eastward of the Youghiogheny River. The axis of the swamp is not a mathematically straight line, but rather sinuous and having a general trend of about N. 65° E., or midway between the butts and faces of the coal.

It would prove interesting and valuable to have one of these great lines of depression accurately portrayed and located through a series of connected workings, and until such is done we can know very little about their real shape. Their production was probably due to the settling after the Appalachian uplift which made the present anticlinals and synclinals.

From the Old Eagle works, the coal rises to the south-east gently to cross the subordinate axis dividing the main Waynesburg Basin, just as it has already been shown to do further east along the Youghiogheny River.

This subordinate axis may be located at the north end of Monongahela City, and passing N. E., parallel to the basin lines, to the neighborhood of Industry, on the Youghiogheny. At the *Dry Run Mine*, just outside of Monongahela City, the Pittsburgh coal is at 811′ A. T., but falling south-west gently along the trend of the axis. At Campbell & Bakewell's coal pit, on the opposite side of the river, it is opened at 812′ A. T. From this point to the W. L. Scott coal, on the Youghiogheny, we have no means, in the absence of development, of knowing how high this axis may lift the coal, but it is probably insignificant, for it is nearly

at the same level on the Youghiogheny as on the Monongahela River. It is sufficient, however, to interrupt the drainage of the region.

From the main pit of the Old Eagle works, at 770′ A. T., the coal rises 11′ to the Horner pit 700 yards; it lies nearly flat for the next 1400 yards to Horner's upper pit, at 780′ A. T., and then rises 32′ to 812′ A. T. at Campbell's & Bakewell's pit, 1350 yards further south-east, thus showing a total rise south-east to this subordinate axis of 42′ in 3450 yards, or about 21′ per mile. From somewhere in the neighborhood of the last pit named, the dip of the coal-bed is reversed, descending south-eastward 52′ in 3800 yards, or about an equal rate, to the Rankin coal-pit, at 760′ A. T.

From this point, the coal *rises* south-east on to the Waynesburg axis, outside the district.

Rankin Mine (M. W. Rankin) is situated on the east side of the river, at about 2,500 yards east of the Monongahela City bridge. The opening is at 760′ A. T., or 30′ above Pool No. 3, and marks the bottom point of the southern "swamp" or sub-division of the Waynesburg Basin.

A line bearing about N. 58° E. from here to Suter, marks the approximate trend of this sub-basin between the two rivers.

The mine is worked on the single entry system. A short distance in from the pit mouth the entry forks; that to the left or west being called the main or Wilson entry; that to the east or right, the swamp entry.

Rooms No. 1, 2, and 4, are turned off at right angles from the swamp entry to the south-east, and the coal rises in all of them from the swamp.

Entry No. 3 is turned off from the swamp entry just beyond No. 2, and bears to the N. W. to the Wilson entry. The coal rises in this also. Above No. 1 there is likewise a connection driven N. W. to the Wilson entry, and called the "Little Entry." The coal rises in it. So, therefore, we find that the drainage is all towards the swamp. But, at the junction of No. 3 and the Wilson entry the coal is flat, low, and soft, and a small roll takes place, which throws the water to the north-west. This is probably only temporary, however, and to the west of this the coal undoubtedly rises.

The swamp entry is practically level from the pit mouth to near No. 4 entry, where there was about three feet of water, (Aug. 17,) but to the north-east the swamp is rising. The flatness of the entry will, however, compel hauling the water or pumpage.

In the swamp entry between Nos. 1 and 3 the coal shows:

Lower division.	Main over-clay,	0'	8"
	Breast Coal,	3'	6"
	Bearing-in Coal,	0'	3½"
	Brick Coal,	1'	4"
	Lower Bottom Coal,	1'	6"

Above the main clay the roof division shows about 31" coal with the usual slate partings, above the slate, 15", and then 6"–7" coal and 12" of slate.

They mine the three upper benches of the lower division, about 4½' thick, and leave the lower bottom coal in the floor. The roof is generally very good and firm. A considerable clay vein shows in the Wilson entry, coming down from the roof and through the breast coal, and rolling the coal to the west of it. This seam of clay bears north and south.

John Perry & Co. are the recent lessees, who were just preparing, in August for active mining. The lessors here require 20-foot pillars to support entries, which is unusually large for this region of low coal.

A general section outside the swamp entry shows:

Roof division.				
Carbonaceous shale,	0'	4"		
Coal,	0'	8"		
Clay,	1'	3"		
Coal,	0'	7"		
Coal,	1'	0"	4'	0½"
Clay,	0'	2"		
Coal,	0'	10"		
Slate,	0'	½"		
Coal,	0'	2"		
Main clay parting,			0'	10"
Lower division.				
Breast Coal,	3'	0"		
Bearing-in Coal,	0'	3"	5'	8"
Brick Coal,	1'	0"		
Lower Bottom Coal,	1'	5"		

Comparatively little acreage has been mined here, the mine only having been opened in 1880.

Milesville Mines are located 1600 yards due east from Rankin's works, and about ¼ mile above the village of Sunnyside. The Milesville Coal Company here controls the coal of J. Wall and J. M. Wilson. The mine was opened in 1864, and has since changed hands several times. I believe Messrs. Lynn & Jenkins are the present proprietors. The present (new) entry is about 60′ above the river, at 790′ A.T., and is shown on the larger map. The old entry, some 400 yards further east, was driven through to the crop on a branch of Becket's run, and this part of the field is worked out and abandoned. The present operations extend from the new pit westward to the stream in Sunnyside Hollow, cropping in the rear of Miller's house at the road forks, the coal all dipping north-west.

This mine could not be examined, owing to the "shut down" of the summer of 1885 and the absence of all human beings connected with it. From the appearance of the coal just within the pit mouth, its section is practically the same as the Rankin mine, giving about 4′ to 4′ 6″ of available merchantable coal. All shipments are for the river trade.

This mine is within 300 yards of the county line, at Becket's Run, up which the coal outcrops for about 1200 yards to the forks of the public road and turnpike, near James Wood's house, just beyond Sutton's pit.

This stream marks a line of fault, bearing about N. 40°–45° E., and mentioned in Mr. Wall's report, K^4, p. 57.

It is quite possible that this fault may extend right through to Douglass Hollow, and so explain the variable elevations on the north and south side of Howell's Run.

The difference is about the same on both rivers, viz., 20′ between the crops on opposite sides of the stream. In direction, it is practically parallel to the *Waynesburg Anticlinal*, and *not* parallel to the apparent rolls in the basin, so that the rise of the former may have caused the break.

At the Becket's run or "Rea" mines, just south of the county line, the Pittsburgh Bed is opened at 803′ A. T., and is *rising* thence *up* river to the Waynesburg axis. Down

the river, the coal falls 23′ to 780′ A. T. at the point of the hill, on the county line, 165 yards from the Rea Mine pit mouth. Just across Becket's Run the coal crops at 801′ A. T., or *21′ higher* than the south crop, or a *downthrow on the south.* On the Youghiogheny, at Howell's run, the reverse is seen, the coal on the north side of the stream, opposite the Pacific Mine, being 22′ *lower* than the south crop. On the ground at either place, but little outside, the coal levels indicate a fault; but in neither instance are the two coal crops over 225 yards apart, and their difference averages 21′ in elevation from crop to crop.

Chapter IV.

Notes on the Mountain Limestone

(at the base of No. XI,)

in the Washington County Gas Wells.

By Professors Alonzo Linn and Edward Linton.*

During the summer of 1885 we made collections of specimens of drillings from two oil wells, the Farley and Wilson, in the vicinity of Washington. These specimens were carefully dried and examined, and stored away for future reference.

One rock especially interested us, and we wish to call your attention to it. It is a limestone that occurs a little more than 1100′ below the Pittsburgh Coal. We had observed a limestone at this depth in the Gantz well, which was drilled the preceding winter, and named it the Mercer Limestone.† Its thickness, however, was unprecedented for that limestone, for it was reported to be more than 20′ thick. We did not examine the specimens of the rock lying beneath it, reported by the drillers of the Gantz well as "a hard white sand, 90′ thick."

In the Farley and Wilson well the 20′ limestone occurred at about the same depth (in the Wilson 1126′) below the Pittsburgh Coal. When we examined the drillings of the rock underneath it, called by the drillers "a hard white sand," we were surprised to find that it was a *lime-sand*, or *siliceous limestone*. The whole thickness of this rock, including the upper pure limestone, was 80′; and it rests on a hard white sandstone, which the drillers do not distinguish from it.

***Communicated to the State Geologist, at his request, March 4, 1886.**

† See Reports of Progress Q^2, Q^3, and others.

We at once suspected that this was what Prof. J. J. Stevenson, in Report of Progress K', on Ligonier Valley, calls the *Siliceous Limestone* (the *Mountain Limestone* of other reports) at the base of Formation No. XI.

We have collected a great many specimens of this rock from many different wells, and find their character so uniform and well marked that we can at once recognize them by a glance through a magnifying glass. This is the only rock in the whole series of our drillings which can be thus certainly recognized.

The upper part of our rock is a tolerably pure limestone about 20′ or more thick. This is of a flinty-brown color, inclining to bluish, and in thin flakes looks as though it had weathered white, and it presents a flinty fracture. It is immediately followed by a siliceous limestone or lime-sand more than 60′ thick. Near the bottom a layer of limestone occurs very similar to the upper part of the rock. The drillings of the lime sand are generally fine sand, and it is difficult to obtain chippings. By patient sifting, however, we succeeded in finding many pieces a quarter of an inch and larger in diameter.

These chippings, under a magnifying glass, show that the rock is composed of grains of quartz more or less rounded, and other well-rounded opaque grains embedded in a matrix. When a fragment was placed in acid it effervesced as freely as limestone, and when all the carbonate of lime was dissolved the fragment still retained its size and shape, but when touched with a glass rod it crumbled to grains of sand.

We carefully picked out several of the opaque rounded grains and placed them alone in acid; they dissolved with effervescence, gradually growing smaller until they entirely disappeared, leaving a few flakes of insoluble matter.

The rock, then, seems to consist of grains of quartz, some of feldspar, and rounded grains of carbonate of lime, embedded in a matrix of carbonate of lime, and thus held together. This character it preserves throughout its thickness of 60′, although some parts are nearer a true limestone, and break with a flinty fracture, and other parts resemble

a conglomerate with well rounded miniature pebbles. No doubt larger pieces of these, if seen, would present an oölitic appearance, with grains about the size of mustard seeds.

We made several thin sections of the chippings of this lime-sand, and mounted them in Canada balsam for the microscope. When these are viewed with a power of 80 or 100 diameters, they beautifully show the structure of the rock. The grains of carbonate of lime are very regularly rounded, and, when rendered very thin, seem to show internal structure, either from being concretions or rounded fossil remains.

We prepared some thin sections of the chippings from the upper purer limestone. These, when magnified about 100 diameters, show many stem-like fossils and numbers of *Foraminifera.*

We obtained some specimens of the *siliceous limestone* from the Ligonier Valley, and, when we compared these with our drillings, we found a remarkably close similarity. Some parts of the drillings were like the Ligonier rock in color, composition, and structure; but the larger part of our drillings was more pebbly or grainy, and produced a white sand.

We prepared several thin sections of the Ligonier rock also, and, under the microscope, the similarity to our rock became still more striking. In some of these thin sections the grains of lime were more elongated than in our lime-sand, and we thought that we detected marks of fossil origin. They presented the appearance of being fragments of some kind of stems, but the marks were obscure, since they had been rolled, and worn, and much rounded.

From this close examination, and from the comparison of our drillings with the *siliceous limestone,* we feel convinced that the rock which occurs 80′ thick in all our wells, about 1100′ below the Pittsburgh Coal, is the same rock which you and Dr. Stevenson have described in the gaps of Laurel Hill and Chestnut Ridge as the Mountain or Siliceous Limestone at the base of No. XI.

We have received specimens of the drillings of this rock

from a well at Claysville, about 9 miles west of this place, and also from the Patterson well, near Cross Creek, about 12 miles north-west. These agree with our specimens, except that the upper part of the rock is a purer limestone, which seems to grow thicker towards the west. We have made arrangements to secure specimens from wells as far west as the Ohio river, and hope in this way to trace the rock nearly to its outcrop in Ohio.

The top of the Piedmont Sandstone is reached in our wells about 950′ below the Pittsburgh Coal, and 170′ above the Mountain limestone. This Piedmont Sandstone is a hard, porous rock, about 50′ or 60′ thick, and usually gives much *salt water*, and sometimes *gas* is found in it.* Between it and the Mountain Limestone some sandstone is passed through, one or two very thin seams of coal, a little thin limestone, some shales, and a seam of fire-clay at least 6′ thick, which our drillers generally report as limestone, because it drills like limestone.

Immediately above the Mountain Limestone there are more than 30′ of black shales more or less calcareous.

The Mountain Limestone has a certain practical significance, since, from the top of it to the usual "gas-sand," is, in round numbers, 700′, and to the "Gordon sand," or the "Third Oil sand," it is about 1000′, or a little less.

Along with this communication we send you some mounted thin sections of our rock, in order that you may compare them with our description.

* The name *Piedmont sandstone* was first used by W. G. Platt in his Report of Progress, H[3], on Somerset county, 1877, (see text and section page 180,) for the top 30′ of the POTTSVILLE CONGLOMERATE FORMATION, No. XII, borrowed from the local sections of the Cumberland coal basin in Maryland. It was afterwards used by I. C. White in his first Report of Progress Q on Beaver county, but immediately replaced by the name *Upper Homewood sandstone*. In subsequent reports it is called simply *Homewood sandstone*, overlying the Connoquenessing sandstone.

[*Note by the State Geologist.*—The practical utility of such an investigation as that which Profs. Linn and Linton, of the College at Washington, are pursuing needs no comment. It is not always easy to distinguish the real difference in the drillings from two rocks of a bore-hole; and yet the whole theory of that particular bore-hole may depend upon properly making such a distinction. In fact, one of the chief obstacles to the early understanding of the

oil measures was the prac ice of passing through limestone beds without noticing them, and calling them by some other more familiar but quite erroneous name. The limestone beds are after all our best key rocks; and they differ among themselves so much that each one furnishes by itself an independent base of measurement. I have no doubt that well-drillers in the new region of Washington, Greene, and the Pan-handle already appreciate the great value of Profs. Linn and Linton's discovery of the Mountain limestone group of XI spreading through the underground of the region, at a depth of 1100' beneath the Pittsburgh coal, and thickening westward and southward.

In 1875 I recognized it in the record of the Boyd's Hill well, at Pittsburgh, and connected it with the *Siliceous limestone* of the Conemaugh gaps and the sub-carboniferous limestone of the Mississippi Valley. See Report of Progress L, page 227. It occupies the 25' interval between depths 889' and 914' in the Boyd's Hill well, the top of which is calculated to be (allowing for dip) about 250' below the Pittsburgh coal, which would make the top of the *Siliceous limestone* at Pittsburgh about 1140' beneath the Pittsburgh coal. It lies at Pittsburgh upon 80' of white sand rock, the top member of Formation No. X.

The drillings of the 25' limestone in the Boyd's Hill well, preserved in the old jar, looked like fire clay, mixed with fine sand grains. None would suppose it to be limestone, without touching it with acid to make it effervesce, or else putting it under a microscope of high power to see the mixture of crystals and grains of lime and grains of sand, with fragments of corals, &c.*

The description of the Washington county wells, given in Profs. Linn and Linton's letter, relates plainly enough the history of the deposit. First, there occurred a great deposit of nearly pure white sand; then a deposit of lime took place while the deposit of sand continued; finally, the sand stopped and lime alone was deposited.

It would serve no good purpose to insert in this volume a drawing of a remarkable microscopic form (among many others) which we have found in one of the specimens. The drillings are under examination, and all the forms discoverable will be published in the next report of the Survey.—J. P. L.]

---

*It is interesting to see how knowledge gradually advances. Whoever made the record of the Boyd's Hill well identified this limestone with the *Kittanning limestone*, lying 200' higher in the series, just as Profs. Linn and Linton at first identified it, in the Farley & Wilson wells, with the *Mercer limestone*, which lies 100' higher in the series.

The Coal-Beds and Fireclays of the Wellersburg Basin, in Somerset County.

By J. P. Lesley.

The south-eastern corner of Somerset county (omitted from the Report of Progress, H[3], because its coal-basin required further examination) projects east from the Allegheny mountain, and contains five townships. Four of them, Allegheny, Northampton, Larimer, and Greenville, occupy the wilderness valley, 20 miles long and 7 miles wide, lying between the Allegheny and Great Savage mountains; the fifth, Southampton, covers the Wellersburg coal-basin, (the northern end of the Cumberland coal-basin of Maryland,) inclosed between the Great Savage and Little Savage mountains; the latter being the Bedford county line.

The geology of the four townships lying behind the Great Savage mountain is the same as that of the townships in Bedford county lying in front of the Allegheny mountain, and is sufficiently described in Report T[2], by Professor J. J. Stevenson.

The valley has been eroded along a great rock-wave,* with steep dips eastward into the Savage, and gentler dips westward into the Allegheny mountain. The crest line or axis of the wave is very straight and runs nearly through the middle of the four townships, lifting the Chemung strata VIII to the present surface as a belt of shale soil as far south as Brush creek at Johnsburg P. O., and in all the water courses at Will's creek as far south as Pocohontas P. O. From there south into Maryland the Chemung rocks VIII lie beneath the surface, and the Catskill rocks IX occupy the valley from mountain to mountain. The Pocono rocks X are in the mountain walls; the Mauch Chunk red

*The Savage Mountain anticlinal, described in Report T[2], on Bradford county, page 9.

shale XI caps them; the Pottsville conglomerate XII makes the mountain crests.

The drainage of the Savage valley is complicated. Part of its rainfall gathers into the Juniata and flows north; most of it gathers into Will's creek and flows east; some of it about Wirtemberg and Pocohontas gathers into a branch of Castleman's river and flows west through a grand gorge in the Allegheny mountain, to Pittsburgh; the rest gathers into Pine run and flows south into Maryland. The influence of anticlinals upon erosion and topography cannot be better studied anywhere than here.

The Southampton or Wellersburg coal-basin is 3 miles wide at the Maryland line, measured from the conglomerate crest of the Great Savage to the conglomerate crest of the Little Savage mountain. The two crests come together on the Bedford county line of Allegheny township, the west wall being 14 and the east wall 12 miles long. The basin is cut through by Will's creek within 2 miles of its north end. Its east wall is gapped by Gladden's run 4½ miles from the Maryland line; and again just south of the line near Wellersburg. The west wall is unbroken from Will's creek gap all the way south into Maryland.

As a coal-basin its value is so overshadowed by the Georges creek country in Maryland that the mining of its coal beds will be postponed to the future. The great Pittsburgh bed of Maryland spoons out before it reaches the State line, although it is again caught in the top of the highest of the Wellersburg hills, but only for a few hundred acres. Most of the basin is a broken table land of Barren measures, with three small coal-beds. The Allegheny coal series (under the Mahoning sandstone) and the Conglomerate series taken together show five coal-beds, none of them in a very promising condition, although they would bear mining if they were protected from competition with the great Maryland collieries. Until these be exhausted none of the coal-beds on the Pennsylvania side of the line could support a colliery.

In the matter of *fire-clay*, however, the case is different. The Mt. Savage fire clay bed (over the Conglomerate) outcrops

on both sides of the basin its whole length in Somerset county, and is successfully mined on Will's creek, as described by Mr. Harden further on.

On account of the absence of mining operations our knowledge of the coal measures is imperfect. The late Mr. James Macfarlane, one of the Board of Commissioners of the Geological Survey, examined the Gladden's run coal lands in the autumn of 1885; made in company with Prof. I. C. White, formerly assistant geologist of the Survey, a surface section of the Barren measures and Allegheny series; and obtained for comparison with this surface section a record of the well bored at Wellersburg in 1855, kept by the resident physician, Dr. Fechtig. On this survey and these sections Mr. Macfarlane wrote a report, and founded his opinion of the practical value of the coal-field.

Prof. White's section was made on the 23d and 24th of September, 1885, partly on the hill slopes, partly in the bed of the run. The measurements were taken by barometer along the surface on the line of dip. The intervals are given in round numbers, and must be taken as only approximations to the truth. Many of the strata were concealed. The details of the section are therefore defective; but important strata actually exposed could be directly measured. On the whole, this surface section gives a generally true description of the basin.

To verify the section made on Gladden's run, another was made at Wellersburg, from the Pittsburgh bed on Harmon's summit down to the bed of the valley, in which a bore-hole 1207′ deep had been drilled for oil in 1865, the record of which was carefully kept by Dr. S. R. Fechtig, a resident physician of Wellersburg.

Other sections made near Wellersburg by Henry K. Strong in 1855, and in another locality by Prof. Jas. Hall in 1856, were used as collateral guides.

Dr. Fechtig's bore-hole record gives most of the details which are lacking in the surface section; but it gives some of them inaccurately, because the keeper of the record had to depend on the drillings as interpreted by the driller; so that the deeper beds of the hole are evidently greatly mis-

represented, and are in fact disproved by the surface section. On the other hand, the *measurements* of the bore-hole record are more trustworthy than those of the surface section, because the hole went vertically down through horizontal strata in the center line of the basin. In fact they must be exactly correct if correctly reported; for no allowance for dip had to be made, as in the case of the surface section, and such allowance is always a source of error.

The surface section takes in 500 feet above the top of the bore-hole.

The bore-hole was sunk 500 feet below the lowest rock in the surface section, but no record of these 500 feet seems to have been kept.

The section and the record correspond for about 500 feet of Allegheny series coals, *i. e.* from the base of the Mahoning sandstone to the bottom of the Conglomerate, No. XII.

The upper part of the surface section represents the Barren measures outcropping in the hill sides above the mouth of the bore-hole.

Surface Section—Barren Measures.

	Pittsburgh bed, (14' thick in Maryland.)		
	Interval, estimated at		220'
1.	Sandstone and concealed,		110'
2.	Shales and iron ore,		20'
3.	Sandstone and concealed,		75'
4.	*Wellersburg coal,*	*Coal,* 2' 6". Blue slate, 6" to 2' 6". *Coal,* 2' 0".	say 5'
5.	Concealed,		50'
6.	Limestone,	2'	4'
7.	*Coal* and shale,	2'	
8.	Shales and concealed,	75'	90
9.	Sandstone, seen,	5'	
10.	Shales, drab,	10'	
11.	*Coal-bed* reported (by T. Moore, blacksmith,)		3
12.	Shales, sandy,	15'	35'
13.	Sandstone, massive,	20'	
14.	Iron ore, sandy, block,		0' 6"
15.	Shales, dark and concealed,		60'
16.	*Coal,*		2' 4"
17.	Limestone?		

18.	Shales and sandstone,			60′
19.	*Saw Mill coal*,	*Coal*, 2′ 0″ to 3′ 0″	4′ 6″	10′ 6″
		Slate, 6″ to 1′ 0″		
		Coal, 1′ 0″ to 1′ 6″		
20.	Fire clay,		1′ 0′	
21.	*Limestone*,		5′ 0″	
22.	Shales,			45′
23.	*Rock seam coal*, (reported to be,)			4′
24.	Shales,			say 40′
25.	Sandstone,			25′
26.	*Fire clay* and coal shales?			
27.	Shales and fire-clay,			20′
28.	Sandstone,			50′
29.	*Coal-bed*,	2′ 6″ / 1″ / 6″	say	3′
30.	Concealed interval of			25′ to 50′
31.	*Piedmont* sandstone, at mill dam, in bed of run,			75′
32.	*Coal-bed*, 3′ to 5′,			say 4′
33.	*Fire-clay*,			5′ to 10′
34.	Conglomerate strata, massive,			100′ to 150′
35.	Sandstone, dark shaly,		10′	11′
36.	Shale,		1′	
37.	*Coal-bed*,	*Coal*, 1″ / Slate, 4″ / *Coal*, 3″	say	1′
38.	*Fire-clay*, impure, sandy,			10′
39.	Shales, dark sandy, with *ball ore*,			20′
40.	Sandstone, massive,			35′

Red shale of XI in Gladden Run gap; with iron ore.

Bore-hole record.

1.	Conductor, in loose stuff,	9′	20′	
2.	Slate,	11′		
3.	*Coal-bed*,		1′	
4.	Interval,		19	to 40′
5.	*Saw Mill Coal-bed*,		4′	to 44′
6.	Interval,		25′	
7.	Fire-clay,		10′	to 79′
8.	*Rock seam coal-bed*,		5′	to 84′
9.	Slate and hard sandstone,		34′	
10.	*Black slate*,		15′	to 133′
11.	*Coal-bed*,		1′	to 134′
12.	Fire-clay and slate,		19′	
13.	Sandstone,		4′	
14.	Slate,		15′	to 172′
15.	*Coal-bed*,		5′	to 177′
16.	Slate,		15′	
17.	Fire-clay,		20′	
18.	Sandstone,		8′	
19.	Fire-clay,		10′	

20. *Red* clay,	4′	
21. Fire-clay,	10′	
22. Sandstone, gray,	6′	
23. Fire-clay,	9′	
24. Sandstone,	13′	
25. Slate,	8′	
26. Sandstone,	21½′	
27. Slate,	14′	to 315½′
28. *Coal-bed,*	2½′	to 318′
29. Slate,	3½′	to 321½
30. LIMESTONE,	8′	to 329½′
31. Soft rock,	2′	
32. Sandstone,	9′	
33. Fire-clay,	2′	
34. Slate,	8′	to 350½′
35. *Coal-bed,*	3½′	to 354′
36. Fire clay,	6′	
37. Slates and fire-clay,	24′	to 384′
38. *Black slate,*	2′	to 386′
39. Fire-clay,	6′	
40. IRON ORE,	3½′	
41. Slates and fire-clay,	45′	
42. Sandstone, dark,	3′	
43. Fire-clay,	4′	
44. SANDSTONE, HARD,	22′	
45. Fire-clay and slates,	25′	
46. Sandstone,	22½′	to 517′
47. *Coal-bed,* [black slate?]	4′	to 521
48. Slate,	20′	
49. *Coal-bed,* [black slate?]	3½′	to 544½′
50. Black rock,	4½′	
51. *Coal-bed,* [black slate?]	11½′	to 560½′
52. Slate,	16′	
53. *Coal-bed,* [black slate?]	8′	to 584½′
54. Fire-clay,	8′	
55. Sandstone, gray,	6′	to 598½′
56. *Coal-bed,* [black slate?]	2½′	to 601′
57. Fire-clay,	5′	
58. Sandstone,	6′	to 612′
59. Unrecorded to bottom of hole,	594′	to 1206′*

It is impossible to credit the record of that part of this well section which lies between 500′ and 600′. For, in this interval of 100′, it reports 5 coal beds, 4′, 3½,′ 11½, 8′ and 2½′ thick respectively. For so extraordinary an occurrence we must ask better evidence than that of an ordinary bore hole. Most of the so-called *coal* is probably black and gray slate, with thin plies or beds of coal mixed in drilling.

*The record says 1207, but there are two slight errors of transcription in the manuscript.

The intervals, however, are probably correct, and especially the thicknesses of sand rock layers, to which the driller's hand and the edge of his bit are both delicately sensitive.

The great quantity of "fire-clay" in the record must be taken as merely *soft rock*—shale of various quality—only a percentage of which would prove to be on trial good fire-clay. The unusual number of strata marked "fire-clay" is explained by the fact that it is commercially a fire-clay region, and the very valuable Mt. Savage fire-clay-bed was looked for as the drill went down. This produced a tendency to regard every soft shale stratum as a fire-clay-bed, and it was so recorded.

The absence of limestone in the record is not surprising, for limestone is scarcely recognized by a driller. If it be soft, he calls it shale or fire-clay; if hard, he calls it sandstone, or merely hard rock. Only when the stratum is very thick and splintery does it awaken his curiosity, and then he may learn from some one that it is limestone. As fire-clay beneath a coal bed in one place will be argillaceous limestone in another, and as siliceous limestone will turn into sandstone, the drill may go down through a series of limestones where they are all too impure to be recognized by the driller.

The extensive tract of Gladen's run coal lands is accessible through the fine natural gap just west of Cook's Mills station on the railroad, nine miles north of Cumberland.

High hills border the main branch of the run on the north. Two or three ravines of no great depth, and opening southward into the valley of the run, give access to some of the upper coal beds of the well record, especially No. 5, known as the saw-mill bed. This bed is supposed to be the coal-bed No. 19 of the surface section, cropping out at no great distance from the bore-hole; but it is remarkable that the bore-hole record takes no account of the five foot limestone underlying the saw-mill bed in the surface section.

The *Saw-mill coal-bed* where opened at the surface consists of two benches, the upper varying from 2′ to 3′, the lower from 1′ to 1½′, parted by slate from 6″ to 12″ thick.

The driller reported it 4′ solid coal, which it may possibly be where the bore-hole passes through it, although the unreliability of the record as to the character and thickness of many of the reported coal-beds is indubitable.

The *Rock seam coal-bed*, struck by the driller 35′ beneath the Saw-Mill coal bed and called by him 5′ thick, was seen as a mere outcrop on the surface. By its blossom it was estimated to be perhaps 4′ thick, and the interval was calculated or estimated at 50′. At the upper limit of this interval of shaly rocks, just under the Saw-mill coal, the five-foot limestone crops out.

On account of this accompanying limestone, and on account of the depth at which it lies beneath the Pittsburgh bed, estimated by Prof. White at 740′, he is disposed to identify the Saw-mill coal-bed with the important *Freeport Upper coal-bed* of western Pennsylvania; but this identification is rendered unsatisfactory by the fact that four coal beds in the neighboring Salisbury basin lying in this part of the coal measures have similar limestones underlying them, as is shown in columnar section Plate X, on the 181st page of Report H^3; these four coal-beds and limestones occupying an interval of only 150′.

A black slate formation 15′ thick, overlying a coal bed 1′ thick and underlying the Rock-seam coal by 34′, is a remarkable circumstance in the bore-hole record, and it may be compared with the heavy black slate roof of coal-bed D., in the Salisbury section.

The five-foot coal-bed No. 15, 38′ lower in the bore-hole, that is, 130′ beneath the Saw-mill coal, seems to represent coal-bed No. 29 of the surface section; but the estimated distance of this beneath the Saw-mill coal is 190′. The driller was probably mistaken in thinking that he went through 5′ of coal; for in the surface exposure of coal No. 29, there appears only 3′ of coal, parted by an inch of clay, the bed being scarcely workable.

Sandstone prevails underneath this in the bore-hole, and also at the surface in the neighborhood of the mill-dam. The record gives four heavy strata of sandstone, aggregating nearly 50′ of sand rock, separated by shales and clays,

in an interval of 90′. The sandstone formation may represent the Clarion sandstone of western Pennsylvania.

Soft rocks, shales, fire-clays, thin coals, or black slates, one limestone 8′ thick, one sandstone 9′ thick, and one iron ore stratum 3½′ thick occupy the next 135′ down to No. 41 of the bore-hole record; but this statement respecting the thicknesses of limestone, coal, and iron ore must be accepted with hesitation until verified by explorations at their surface outcrop.

One of these coal-beds is said to be 3½′ thick with 6′ of fire-clay under it, and it lies in the bore-hole 310′ beneath the Saw-mill coal. It, therefore, corresponds with sufficient closeness to No. 32 coal bed in the surface section, estimated to lie 318′ beneath the Saw-mill bed, to be from 3′ to 5′ thick, and to have under it from 5′ to 10′ of fire-clay, supposed to be the Mount Savage fire-clay-bed, resting upon the great conglomerate.

There is, however, not an absolute certainty in this identification; for, in the bore-hole no sandstone is struck for 80′ beneath the coal bed, that whole interval being occupied with soft rocks.

A second great sandstone formation, which is undoubtedly part of the Pottsville conglomerate No. XII, appears at 447′ down the bore-hole, and continues to 517′ *i. e.*, from No. 42 to No. 46. In this interval of 70′ there are three sand rocks, 3′, 22′, and 22½′ thick, respectively, with shales and fire-clays between them.

The next 90′ consist of slates, some of them black enough to deceive the driller into reporting huge coal beds, with fire-clays, and one sandstone, only 6′ thick. But, in the surface section this soft formation is only represented by 42′ of shales, containing 1′ of coal, a great bed of fire-clay 10′ thick and some nodules of iron ore. It is evident that while the description of the measures in the bore-hole record has little value, it is equally evident that the surface section is imperfect. In future explorations, however, the actual measurements of the bore-hole record will be of the greatest service as a guide.

The bottom member of the Pottsville conglomerate, (No.

40 in the surface section) is estimated at 35′. In the bore hole only the first 6′ (No. 58) is recorded, and then the record stops, the well going down 594′ further; that is, to a total depth of 1207′; or, by putting the well record and the surface section together, to a total depth beneath the Pittsburgh coal of 1766′.

The center line of the basin crosses Gladen's run at J. L. Kennet's mill.

The coal lands occupy an elevated mass of hills formed by the massive sandstone formation overlying the Saw mill run coal; the massive sandstone formation in the third hundredth feet of the bore hole, rising to the surface east and west, and rising also slowly northward along the axis of the basin. The softer rocks underneath make a deep depression all around this central mass of hills to the east and to the west; and Wills creek has taken advantage of it to the north for cutting its channel clean across the basin. The surrounding depression is again itself walled in by the underlying Pottsville conglomerate rocks rising east and west to make the two mountains.

The central mass of hills rises to a height of 575′ above Gladen's run at Kennet's mill, and contains not only the whole of the coal measures represented in the bore hole, but about 500′ of Barren measures overlying; not enough however to take in the Pittsburgh coal, the amount of erosion from the hill tops up to the Pittsburgh coal being estimated at 220′.

The country between Gladen's run and the State line is of the same character, the coal beds of the bore hole sinking slowly in that direction, the central mass of hills gradually widening, although not much, and more and more of the upper part of the Barren measures being preserved in the hill tops, until finally one of them is high enough to hold a little outlying patch of the Pittsburgh bed. This patch is in Harman's Summit, on the wagon road just north of Wellersburg. Harman's Summit is the highest point (on the center line of the basin) of the high divide which joins the two mountains and throws the rainfall north into Gladen's run and south into Maryland. This patch of a

few hundred acres is all that remains of the great bed north of the State line in this basin. Formerly the bed extended to the ridge on Castelman's river, where it is now extensively mined in what is called the Salisbury basin, a full description of which can be found in Report H³. The bed formerly also extended northward over Bedford and Huntingdon counties, for a small patch of it is left in the summit of a high peak in the Broad Top coal-region. It is known to extend southward through West Virginia, and it no doubt once spread eastward over Fulton and Franklin counties, as it still does through south-western Pennsylvania.

The coal beds of the Barren measures are unreliable; one or two of them are locally workable, as described in Report H³ around Berlin and Ursina. Four of them appear in the hills of this Wellersburg basin, but do not give much promise. They are marked in the surface section as No. 4, No. 7, No. 11, and No. 16; No. 4 being the highest and called locally the Wellersburg coal.

The *Wellersburg coal-bed* (No. 4) has been mined for local use in two benches separated by a blue slate which thickens to 2½′ and thins to 6″. The upper bench is 2½′ and the lower bench 2′. It lies, by estimation, 430′ beneath the Pittsburgh bed, and therefore corresponds to the Price bed at Berlin, which lies, by estimation, 375′ beneath the Pittsburgh bed.

A slaty coal-bed (No. 7) 2′ thick underlies the Wellersburg bed about 50′, and would correspond with the Coleman bed at Berlin. But the Coleman bed has a 3-foot limestone under it, while this No. 7 coal has a 2-foot limestone for a roof.

Coal-bed No. 11 lies about 144′ beneath the Wellersburg coal and is reported by Mr. Moore, the blacksmith, to be 3′ thick. It may, perhaps, correspond to the Philson bed at Berlin, which, however, lies only about 100′ beneath the Price, and has a well defined limestone under it which is not reported by Mr. Moore.

Coal bed No. 16, 2½′ thick, has a limestone under it and nothing to correspond with it as a coal-bed at Berlin.

The fact is the surface section of barren measures in this

Wellersburg basin is so imperfect, and we know so little of the way these coal-beds vary, and so little of the limestones which accompany them and which are notoriously liable to the greatest variations, that we are in no condition for determining the identity of the barren measure coals in the Wellersburg basin with the Salisbury-Berlin basin, except in a general way. It is entirely probable that the Wellersburg coal and the three coal-beds under it are the four beds at Berlin, viz.: the Platt, the Price, the Coleman, and the Philson. From the Wellersburg coal, down to the No. 16 coal, is estimated at 240′. The distance from the Price down to the Philson is estimated at 200′.

It is not likely that any of these barren measure coals will have a market value for a long time to come.

The center line of the basin southward crosses the State line at the stone grist mill just south of Barrelville; but although the basin deepens into Maryland the hills are cut down lower and therefore do not contain the Pittsburgh bed.

All the coals of this basin are semi-bituminous, containing from 16 to 18 per cent. of volatile matter, the quality being excellent, the only drawback being the comparative smallness of the beds and the overpowering competition of the great Pittsburgh bed in the Maryland part of the basin. This is the opinion which the geologists of the State have always entertained, and it is confirmed by Mr. Macfarlane, whose knowledge of the coal-fields of the State was excellent. There are surface openings on several of the coal beds. Only one opening, however, has been made in the whole region on what is considered its best bed, (No. 29 of the surface section,) the upper one of the two beds which have been opened at Tauber's fulling, mill on the south side of Gladen's run, the thickness of which however, has been variously reported.

The altitude of Kennel's mill above the Baltimore and Ohio railroad at Cook's mills is (by barometer) 450′; the distance about 4 miles. A survey for a railroad is said to have been once made, but no recorded profile of it could be discovered; but the line is evidently an easy one.

Much of the land is covered with excellent timber, of

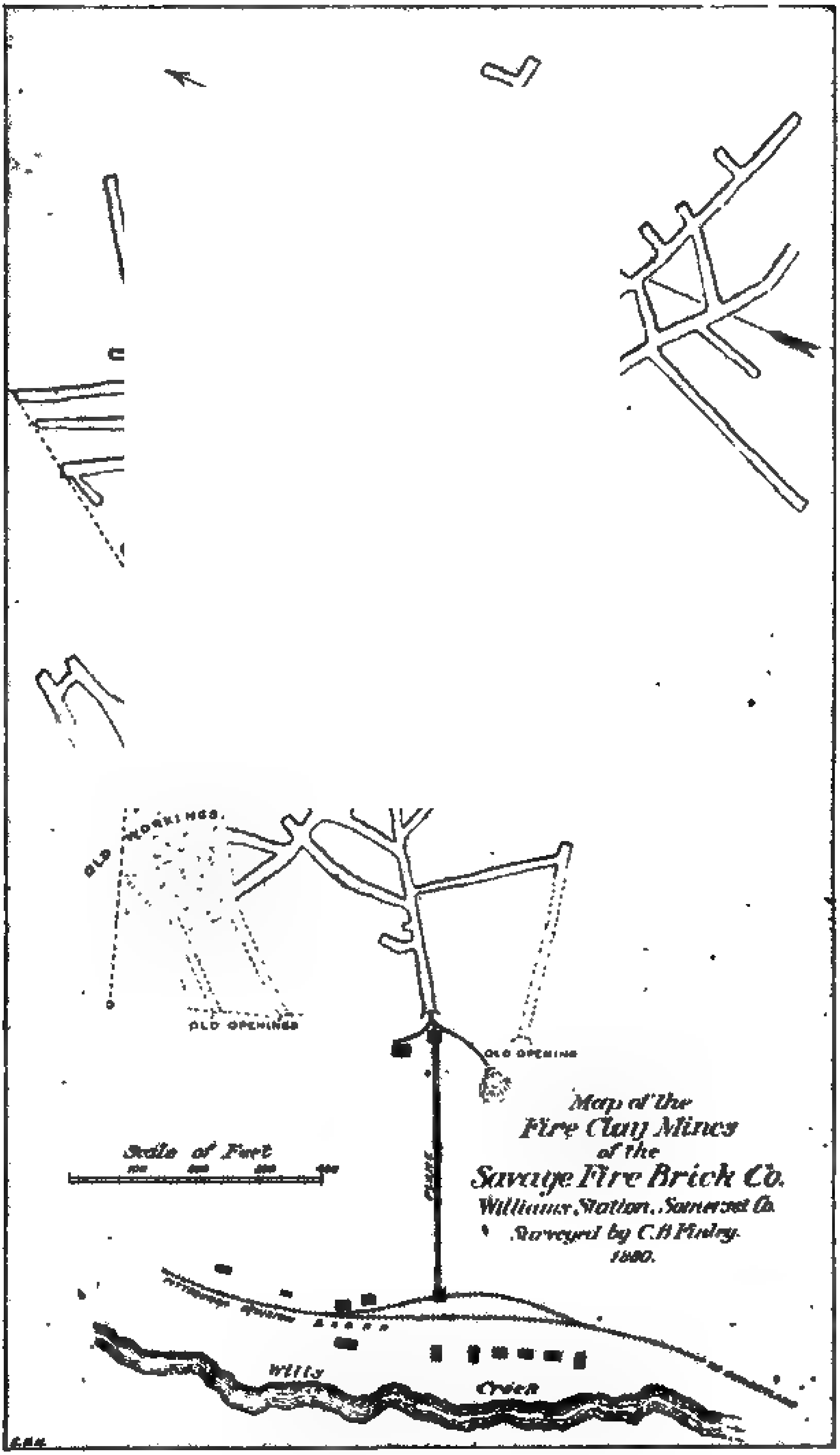
which the white oak is most valuable. A responsible lumberman of Cumberland offers $1.50 per M b. m. for it, and says he is paying $2.50 for it within half a mile of the railroad, only trees more than a foot in thickness being taken for lumbering purposes. If mines were opened, the timber should be saved for colliery use.

Report on fire-clay, by Mr. E. B. Harden.

Wills creek, flowing south-east from Fairhope, cuts its way down through the Conglomerate No. XII, and red shales and sandstones of No. XI, exposing a fire-clay-bed along the face of the mountain about 300 feet above water at Williams station. Two openings have been made on the north-east side of the creek in Allegheny township, Somerset county.

The North Savage Fire Brick Company's mine, owned by Welsh, Palmer & Maxwell, on land of H. T. Weld, was opened in September, 1881, and is entered by a drift on the clay, 327 feet above Wills creek at Williams station, on the Pittsburgh division of the Baltimore and Ohio R. R. The drift follows a general course of N. 53° E. It is about a thousand feet long and is carried around the heads of old chambers coming up from the adjoining mine on the south-east, making a curve to the north in its course which carries it up the pitch and makes a summit about one-third the distance in. The direction now being driven at the face of the heading is N. 45° E. The small quantity of water made in the mine drains into the workings on the south-east. The thickness of the clay at the face of the heading varies from 10 to 12 feet, a large portion of it being hard or "flint" clay.

The chambers are driven off the main heading to the right and left, from 12 to 14 feet wide, as the nature of the clay will permit; those on the north-west side are short, being stopped when reaching what the miners term "sandrock," a hard sandy clay which runs in a north-east course across the bed. The chambers on the south-east side are limited


OLD WORKINGS.
OLD OPENINGS
OLD OPENING
Map of the
Fire Clay Mines
of the
Savage Fire Brick Co.
Williams Station, Somerset Co.
Surveyed by C.B Finley.
1880.
Scale of Feet
Wills
Creek

in length owing to the proximity of the property line. The extent of the sand rock is not known, not having been driven through; at one point in the main heading it comes up from the floor entirely cutting out the clay; and in the room to the north-east nearest the end of the heading the sand rock is struck in the roof at 15 feet; and in a few feet further it descends reducing the clay to 6 feet, where the chamber is stopped. Mr. Thomas Maxwell, the superintendent, intends driving this chamber, if possible, through it.

The clay bed varies in thickness in this mine from 4 to 15 feet, and is composed of hard or "flint" clay, and soft or plastic clay, without a parting of any other material between them. The two kinds of clay do not hold any regular position one with the other, the hard clay being sometimes on top and again below. The miners say, however, that the hard clay is more often found below the soft. The proportion of hard and soft clay is not constant, and varies in a few feet from nearly all hard to nearly all soft clay.

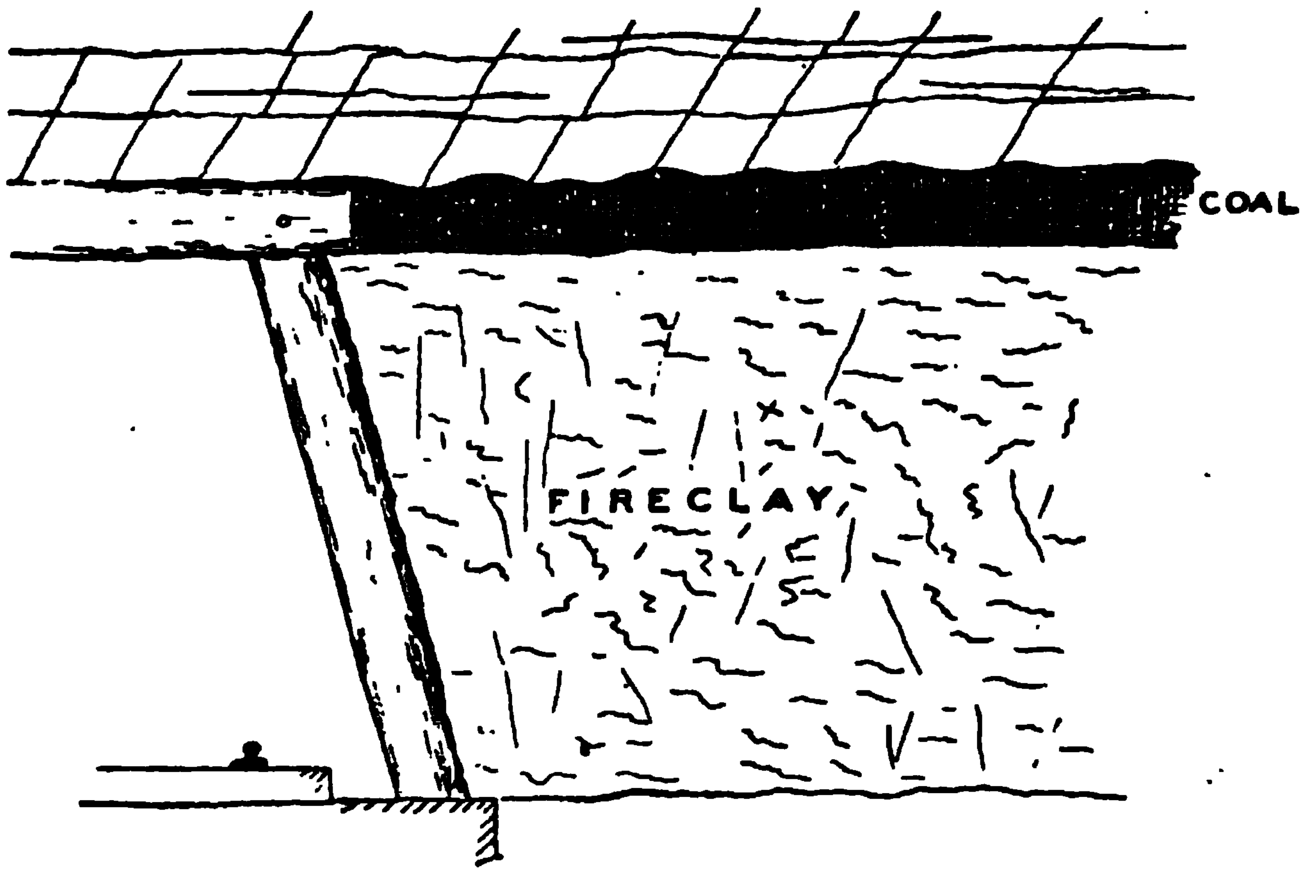
The hard clay is light gray in color, and most of it has minute veins or darker colored clay from $\frac{1}{50}$ to $\frac{1}{20}$ of an inch thick, running in all directions through it. It is very dense and hard, and when exposed to the weather it does not readily disintegrate.

The soft clay is a lighter gray in color and is greasy to the touch. When exposed to the weather, or to air and moisture in the mine, it rapidly becomes plastic and with much weight upon it will run.

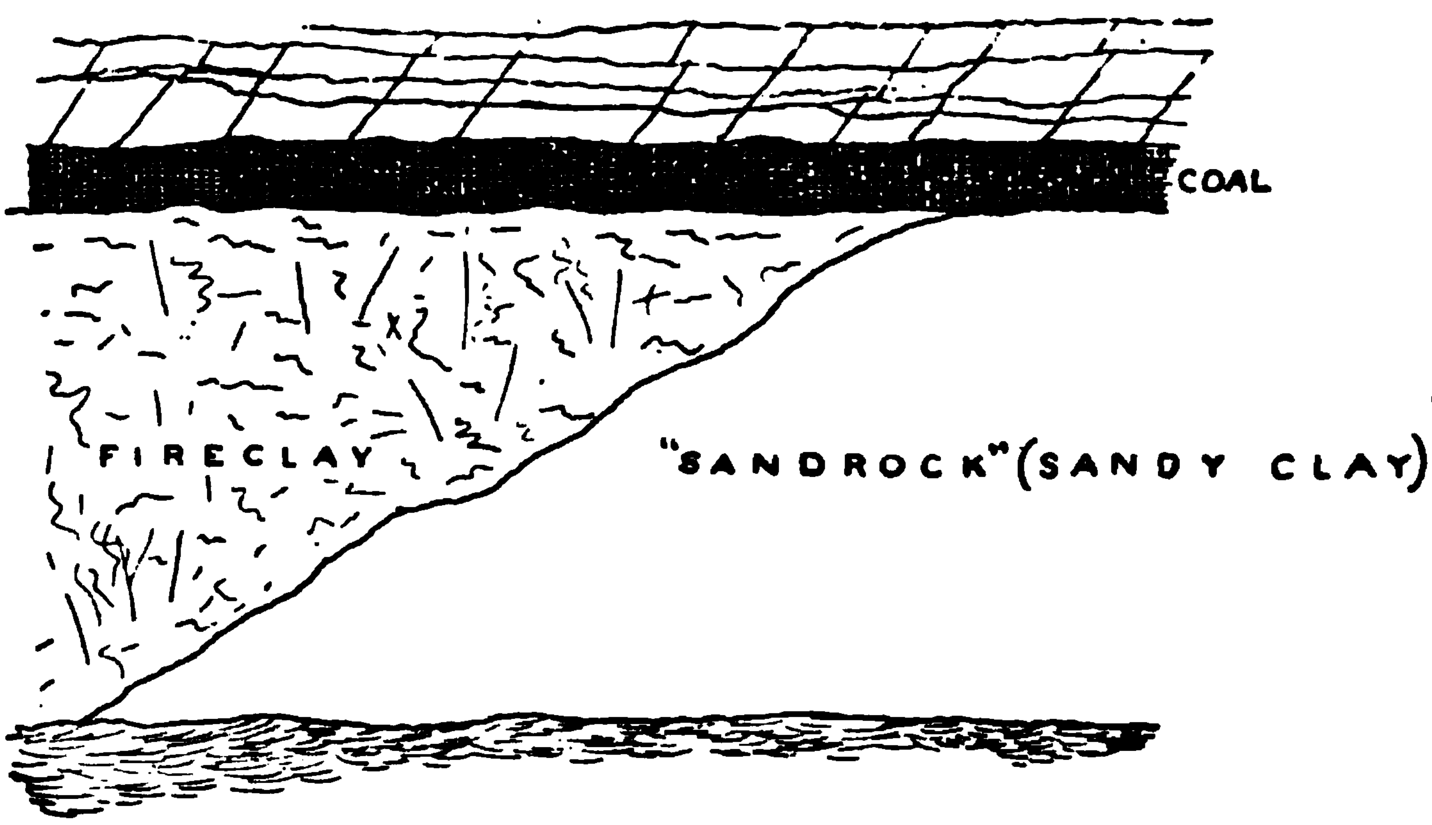
The hard clay is that most sought after, the greater part of the soft clay going to the waste dump.

A small bed of coal from 2 to 12 inches thick is carried on the clay, the upper surface of which is wavy, as is seen in the sketch, made at the mouth of the drift. The coal is taken down in mining, as it separates from the sandstone above, and becomes a source of danger to the miners. When the coal is taken down very little timbering is found necessary, the sandstone making a good roof. This is shown in the old workings where the clay has been robbed out, and the roof and floor are gradually squeezing out the clay pillars and coming together without breaking.

Sketch showing the uneven surface of the coal bed at North Savage mine



Sketch showing the "sandrock" taking the place of the fireclay at N. Savage mine.



E.B.H.

The clay is mined by blasting with powder, holes 2½ to 3 feet deep being made with sledge and drill.

In this mine the work is done by a contractor who delivers the clay at the tipple for a price per cubic yard, and furnishes everything but horse-power and cars.

The clay-bed dips 8 degrees S. 30° E. and a slight depression in the hill to the north-west of the opening swings the outcrop around to the north, allowing the chambers on the north-west side of the gangway to be driven to daylight, if the sand rock, before spoken of, is not found to be too formidable a barrier.

No attempt is made to ventilate the mine other than the natural circulation of the air, but the small quantity of powder used seems to prevent any serious inconvenience in working.

Eight miners, one driver, and one outside man are employed in getting the clay to the tipple.

A section made at the mouth of the drift reads:

Coal,	reported	4 feet.
Concealed,		19
Sandstone, fine, light colored, massive,		10
Coal,		0 to 1
Fire-clay,		12
Shale,		5
Sandstone, current bedded,		—

The steep slope from here down to the bed of the creek, say 300 feet, is completely covered with blocks of sandstone and conglomerate.

Bowlders of conglomerate are seen on the hillside above the mouth of the drift.

From the entrance of the mine to the fire-brick works a tram road 2200 feet long, running north, with a descending grade of one foot per hundred, reaches the head of the plane, which descends 190 feet in elevation to the dump at the works on the bank of the creek. An overhead drum and ⅞ inch wire rope are used, the loaded cars hauling up the empties.

The clay is ground in a revolving pan with stationary rolls, driven by a horizontal engine and return flue boiler, and, when sufficiently fine, is taken out with a shovel and

thrown into a shute leading to the molder's table on the floor below. The clay, after being molded into bricks, is allowed to dry partially, and is then pressed in a machine by hand, the press carrying a die giving the brand for the particular kind of brick being made, after which they are further dried and are ready for the kiln.

The proportion of hard and soft clay is varied to suit the purpose for which the brick is to be used, the hard clay making a porous brick, and the soft clay one more dense. The "No. 1" brick of these works is made of flint clay mixed with one fourth soft clay; other classes and brands are made varying in composition. The "silica" brick is made from the sandstone and conglomerate rocks which line the mountain side, the rocks being ground and mixed with one third soft clay, which makes a porous and very refractory brick, useful in the furnace where a cutting flame strikes.

A red brick is made from clay dug near the works, which appears to be *debris* of the decomposed red sandstones and shales filled with angular pieces of white sandstone. It is ground up in the crushing pan and makes a hard brick. A sample tested at the Keystone Bridge Works at Pittsburgh bore 295,100 pounds, or 584 tons per square foot.

All the clay obtained at this mine is manufactured at the works, and none shipped to other points.

The second opening, on the north-east side of Wills creek, in Allegheny township, Somerset county, is that of the Savage Fire Brick Company. The works were opened in 1870, and three drifts made, but now abandoned. The present drift was opened in 1875, and extends 960 feet N. 56° E., and then 680 feet S. 84° E.; in all, 1640 feet. Two branch headings are made on the north and two on the south of the main gangway, the latter diverging to the south-east. The thickness of clay at the mouth of the drift is 4′ 6″, and it varies in thickness until at 350 feet it is 6 feet thick. At 550 feet from the mouth of the drift the clay is reduced to 2 inches, and at 650 feet it entirely disappears, together with the coal bed on top of it, allowing the sand-

stone to rest directly on the under shale. The clay is thus cut out for a hundred feet; then it comes in again. At 1200 feet it has thickened to 25 feet.

At the present face of the main heading it is from 10 to 12 feet thick. The rolls in the clay make it sometimes necessary to take up the bottom to reduce the grades, and Mr. James Noel, the mine foreman, reports the under shale 4 to 5 feet thick, with 6 inches of coal at the bottom, underlaid by sandstone.

The bed is the same as that worked in the North Savage mine adjoining, and the proportion of hard and soft clay is about the same.

The headings on the south of the main heading are driven partly down the dip; but the mine makes so little water that no difficulty is experienced, ten water cars a week being all that is made in these dip workings. The other part of the mine is drained by a 2-inch syphon.

Several trial openings have been made along the outcrop to the south-east, which prove the continuation of the fire-clay-bed in that direction. A coal-bed, reported to be 4 feet thick, with two inches of slate in the middle of it, has been opened in several places 30 feet above the clay-bed.

Iron ore balls are frequently met with in the clay-bed in this and in the adjoining mine; they occur both in the soft and hard clay, and in all parts of the bed.

Trial shafts have also been put down to the clay-bed by this company near the outcrop, a mile and three quarters north of Williams Station, on the farm of J. Martin, where the basin spoons out to the north-east.

Thirty miners, 3 drivers, and 3 laborers, are employed at this mine in two shifts, the work going on night and day, producing at this time over 100 tons of clay. The men are paid by the car, holding two tons, and are required to get out a certain number for a day's work.

The head of the plane, 570 feet long, is at the drift mouth, and the clay is sent down by means of a drum and wire rope to the works, 250 feet vertically below.

A Gardner's patent three-cylinder engine, by Dunbar & Sons, of Buffalo, drives the machinery of the works. The

clay is ground dry in a Stevenson pan 9 feet in diameter, with perforated adjustable plates, which allow the clay, as fast as ground, to fall through into a hopper. It is then carried to the upper floor by means of a belt and buckets, where it is screened and run into a pug mill, and given the proper amount of water, and thoroughly mixed by a horizontal shaft carrying blades, after which it is sent to the molder's table.

A furnace for calcining the clay has been erected at these works, but was not running at the time of my visit, the necessary amount of calcined clay being obtained from the broken and defective bricks, which are ground up in the same manner as the clay; and the addition of this calcined clay gives the brick, when burned, its maximum shrinkage. The shrinkage from the molded to the finished brick is one inch per foot.

There are three kilns at this place, holding 43,000 9-inch brick each. For the purpose of computing wages, &c., all sizes of brick are reduced to the 9-inch standard.

Forty-eight men and boys are employed here in the manufacture of fire brick, and 300 tons of coal per month are used, principally in firing the kilns, about 30 tons being required for the burning of a kiln of brick.

Clay is prepared here and shipped dry to the other works of the company, at Hyndman, in Bedford county, and Keystone, in Somerset county.

At the mine of this company, at Keystone, the clay became poor in quality, and it was necessary to obtain a supply from another quarter. This led to the location and opening of the present mine, at Williams Station.

On the south-east side of Wills Creek, at Williams Station, the clay bed has been opened 245 feet above the level of the creek, and a drift put in S. 58° W. about 200 feet long. The clay is here 7 feet thick, with an average of 10 inches of coal between it and the roof sandstone. The 4-foot coal-bed has also been opened 35 feet above the clay. All the openings on the coal have fallen shut, and its character and thickness cannot now be seen.

At Ellerslie, 6 miles west of Cumberland and on the Maryland State line, James Gardner's fire brick works, on the Pittsburgh Division of the B. & O. R. R., is supplied with clay from the mines 2½ miles east of Ellerslie, on the summit of the Little Allegheny mountain, 1060 feet in elevation above the railroad (at Ellerslie.)

The mine is reached by a narrow-guage road, 2 miles long to the foot of the plane, rising in the distance 475 feet, and an incline plane half a mile long rising 585 feet; the upper half of the plane being the steepest, and rising at an angle of 22 degrees.

The entrance to the mine is about 40 yards south of Mason and Dixon's line, and within 50 yards of a corner post marking Somerset and Bedford counties, Pennsylvania, and Allegheny county, Maryland. The summit of the mountain has been eroded at this place, making a slight depression or notch in the crest, the mine being on the eastern slope of the divide in the notch, which allows it to be operated down the eastern or outside slope of the mountain towards Ellerslie. The bed dips N. 76° W. from 28° to 30°, the pitch being steeper near the mouth of the drift, which follows a general course of S. 20° W.

The regularity of the dip allows the gangway to be driven with enough rise to properly drain the mine; and the hill rising south-westward gives about 150 feet of a lift near the present face of the gangway.

The hard and soft clay occupy a regular position with each other, the hard clay always being on top and separated from the soft clay by more or less hard sandy clay somewhat resembling the "sandrock" or sandy clay of the mines at Williams Station.

The soft clay being underneath allows of a simple and easy method of mining, the soft clay being taken out first and cleared away for a distance of 15 or 20 feet, when the hard clay is blown down.

The soft clay is harder than that seen at other mines and does not run.

The concretions of iron ore are said to be found always between the hard and soft clay.

There is no coal on the top of this clay-bed.

Near the mouth of the drift the hanging wall of shale has been driven through westward, the shale being 8 to 10 feet thick, and a bed of plastic clay reached from 5 to 6 feet thick, having above it 2 feet of black slate, with a coal bed 6 inches to 1 foot thick on top of it.

On the opposite side of the notch, north-east of the present opening and on the Pennsylvania side of the Line, a tunnel was driven for the purpose of reaching a still higher bed of fire-clay in which the following section was developed and given to me from recollection by Mr. Stultz, the mine boss:

Hard conglomeritic sandstone, the white quartz pebbles being as large as peas,	**32'**
Fire clay,	**2'**
Slate,	**2'**
Coal,	**0' 9''**
Slate,	**2'**

The measures dipping about 30° degrees made the distance driven through double the thickness above given; and finding that another sandstone had to be encountered before reaching the clay, the tunnel was abandoned and is now fallen in.

The first work done at the Ellerslie mine was along the outcrop of the bed, and quite extensive excavations have been made along the crop for a quarter of a mile on a course S. 20° E.

About 70 feet west, and above the outcrop of the clay bed, a ledge of conglomeritic sandstone is seen on the surface, which is undoubtedly the same conglomeritic sandstone passed through in the tunnel on the north side of the notch above described. Several hundred feet west of this sandstone, and higher in the measures, Mr. Stultz informs me a shaft was put down on a clay-bed; but further than that the clay was colored with iron he could give me no information. It has been plowed over and the exact location could not be determined.

Two miners and three loaders, also acting as drivers and plane men, are employed, and 10 cars, holding 2 tons each, are gotten out per day.

The loaded cars run from the foot of the plane to the works at Ellerslie by gravity, and horses are used to bring back the empty cars, each horse bringing up one car and making 5 trips per day.

At the brick manufactory two sets of machinery are in place, but only one engine and crushing pan were running at the time of my visit. The clay is ground and mixed in a revolving pan, the subsequent treatment being much the same as at other works in the region. Three kilns are used for firing the brick.

The three mines described above are the only ones in the region in Pennsylvania, and no other openings on the clays of the basin are known to have been made, and no information can be obtained respecting the clay deposit along its outcrop between Ellerslie and Williams Station.

Report on the Tipton Run Coal Openings, Blair county. (*Coal Beds in the Pocono Formation No. X.*)

BY CHARLES A. ASHBURNER.

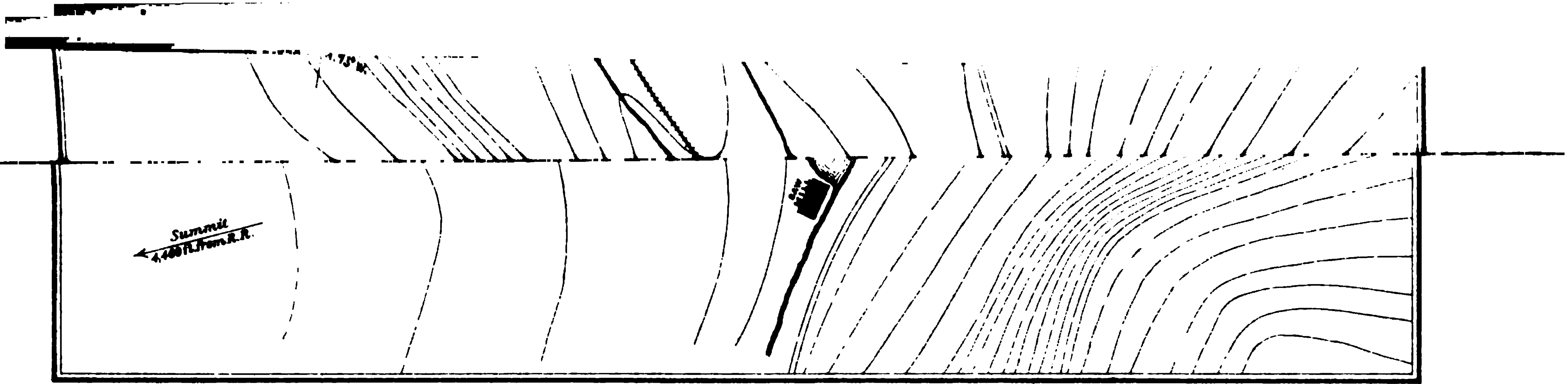
About four miles north of Tipton Station, on the Pennsylvania Railroad, in Antis township, Blair county, and on the lands formerly owned by the Summit Coal Company, limited, but now owned by the newly-organized company known as the Tipton Run Coal Company, there have been opened the outcrops of several (ten or more) coal-beds occurring in the Pocono Sandstone No. X. One of these coal-beds has been opened for many years, and was examined and reported upon by Professor Lesley about 1852.

At the base of the Lower Productive Coal Measures, both in the Pennsylvania bituminous and anthracite fields, occurs a series of beds of sandstones and conglomerates, which, in special localities, contains coal-beds of workable dimensions. In the bituminous fields these beds are known as the Marshburg, Alton, Mercer, &c., coal-beds. In the western part of the anthracite region the Upper and Lower Lykens Valley coal-beds occur in the same formation.

This series of sandstones and conglomerates, with the included coal-beds, is known under the general name of Pottsville Conglomerate, No. XII, on account of the maximum development of the formation being found in the vicinity of Pottsville, Schuylkill county.

Directly on top of the uppermost member of the Pottsville Conglomerate, No. XII, in the bituminous region, occur the productive coal-beds of Clearfield and adjoining counties, and in the anthracite region, all the Coal Measures above and including the Buck Mountin coal-bed.

Immediately beneath the Pottsville Conglomerate occurs the Mauch Chunk Red Shale, No. XI, which is over 2100 feet thick along the Lehigh River, in Carbon county, but

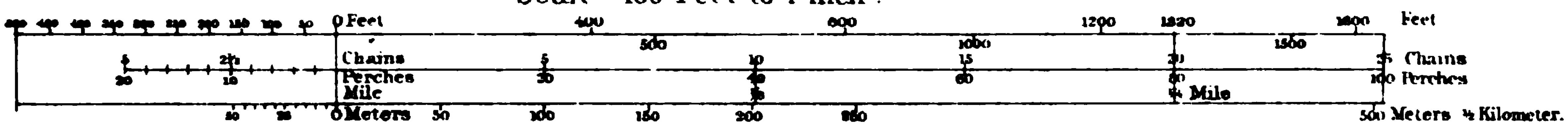


335.

JULIUS BIEN & CO LITH.

E K MEYERS, STATE PRINTER

Scale - 400 Feet to 1 Inch.



$\frac{1}{4800}$ th of Nature

which gradually thins out toward the northern and western parts of the State; along Tipton run it is only 250 feet thick, and it is hardly recognizable in the north-western counties of McKean, Warren, and Forest, where it is probably represented by 25 to 50 feet of shaly strata (not always red) immediately under the lowest member of the Pottsville Conglomerate.

Underlying the Mauch Chunk Red Shale, No. XI, occurs the Pocono, No. X, or the Vespertine Sandstone of the First Geological Survey. To this formation Professor Lesley referred the Tipton coal-bed, which he first examined over 30 years ago, and all subsequent examinations have confirmed his conclusion.

During the progress of the Second Geological Survey a number of coal-beds have been found in this same Pocono Sandstone at other points in the State, so that, in a strictly geological sense, the Coal Measures must be considered to commence at the base of the No. X strata which have always been assigned to the Carboniferous period; but, on account of the uncertain occurrence, thickness, and composition of the coal-beds of the Pocono Sandstone, practical geologists and coal men will continue to consider the Pottsville Conglomerate the base of the Productive Coal Measures proper.

The coal-beds occurring in the Pocono formation in Pennsylvania will probably never be found to possess sufficient thickness to permit of their *extensive mining*, but in special cases some of these beds may be found sufficiently thick and persistent to permit of their being economically mined; this fact, however, will have to be established by actual developments in each individual case, since our knowledge of the characteristics of the Pocono, No. X, coal-beds makes geologists and miners suspicious of their occurrence as *beds of any commercial value.*

One of the most interesting occurrences of coal-beds in Formation No. X is where it encircles the Broad Top mountain plateau in Huntingdon, Bedford, and Fulton counties, forming Sideling hill on the east side of Broad Top mountain, and Terrace mountain on the west side.

In the carefully measured section of this formation, which

I made in 1875, in Smith's and Ground Hog valleys and through the Sideling Hill tunnel of the East Broad Top railroad, the formation was determined to be 2133 feet thick, divided into the following members:

Upper X.	d. Sandstone, massive and flaggy, ...	610′	1808′
Middle X.	c. Coal bearing series, ...	818′	
	b. Conglomerates, sandstones, etc., . . .	380′	
Lower X.	a. Sandstones and shales, ...		330′
	Total length in Sideling hill, ...		2133′

The coal bearing strata contain 19 seams of coal, with an average individual thickness of one inch and a half. Their thickness, if added together, and combined with that of the numerous thinner seams and partings scattered through the strata, and not precisely located in the section, would be sufficient to form a solid seam of coal about four feet thick.

The following analysis of the section shows the position of each coal-bed and the intervals between them, filled generally with sandstone:

	Sandstone interval, thickness, ...	29′ 5″
19.	*Coal*, 2½ inches thick.	
	Sandstone, ...	76′ 8″
18.	*Coal*, 2 inches.	
	Sandstone, ...	1′ 6½″
17.	*Coal*, 3 inches.	
	Sandstone, ...	41′ 4″
16.	*Coal*, 1 inch.	
	Sandstone, ...	2′ 6″
15.	*Coal*, 1 inch.	
	Sandy fire-clay, ...	6″
14.	*Coal*, 1 inch.	
	Sandstone, ...	47′ 1″
13.	*Coal*, 1 inch.	
	Sandstone, ...	6′ 0″
12.	*Coal*, 3 inches.	
	Sandstone, ...	6′ 0″
11.	*Coal*, 1 inch.	
	Sandstone, ...	4′ 0″
10.	*Coal*, 3 inches.	
	Sandstone, ...	2′ 0″
9.	*Coal*, 3 inches.	
	Sandstone, ...	1′ 0″
8.	*Coal*, 1 inch.	
	Sandstone and shale, ...	36 8″
7.	*Coal*, 1 inch.	
	Fire-clay and sandstone, ...	5′ 0″

6. *Coal*, 1 inch.	
Sandstone,	1′ 0″
5. *Coal*, 2 inches.	
Sandstone,	5″
4. *Coal*, 2 inches.	
Sandstone,	17′ 0″
3. *Coal*, 2 inches.	
Sandstone,	28′ 0″
2. *Coal*, 1 inch.	
Sandstone,	5′ 0″
1. *Coal*, 1 inch.	
Black slate plant bed,	25′ 0″

Grouping the coal-beds which lie close together, we have the following series:

Sandstone, top of series,	29′ 5″
One coal-bed, 2½ inches thick.	
Sandstone, mass of,	76′ 3″
Two coal-beds, in 24 inches of space.	
Sandstone, mass of,	41′ 4″
Two coal-beds, in 8 8 of distance.	
Sandstone, mass of,	47′ 1″
Six coal-beds, in 19 10 of distance.	
Sandstone, mass of,	36′ 8″
Four coal-beds, in 6 10 of distance.	
Sandstone, mass of,	17′ 0″
One coal-bed, 2 inches thick.	
Sandstone, mass of,	23′ 0″
Two coal-beds, in 5 2 of distance.	

Fire-clay occurs only under seams Nos. 7 and 15; that under No. 15 being very sandy.

The sandstones between the several seams have a great sameness of character, and are very much broken up by false bedding and fractures; in many cases they contain seams or partings of coal. The numbered seams and partings generally lie parallel with the true bedding of the strata, although in many instances *they are found along the planes of false bedding.* The thicknesses are very variable, in places increasing from 1 to 2 inches up to 10 inches and 1 foot; and sometimes a seam will be very much broken up and separated by a mass of sandstone which splits the bed for some distance, but afterwards disappears, permitting the several portions to unite again.

The almost total absence of fire-clays under the coal-seams and the occurrence of coarse sandstone in many places di-

rectly above them seems to show that the coal has been derived from plants which may have grown at some distance from the locality and been afterwards floated and caught in the falling sediment, forming "drift-beds," although some of the beds which are underlaid by fire-clay are more probably derived from vegetation which grew in place.

In the western end of the Sideling Hill tunnel on the (proposed) South Pennsylvania Railroad, several beds of coal, each about 1 foot thick, are reported, by Mr. F. H. Lewis, Assistant Engineer, to have been cut through.

One or more coal-beds have been found in the Pocono at a number of localities in Pennsylvania. Prof. Lesley states: "A spot has been tested at Duncannon, in Perry county, where one of these beds seemed promising but proved worthless. Another such spot has been tried, with the same want of success, at Mt. Patrick, higher up the Susquehanna."

A No. X coal-bed was mined to a limited extent in Maryland, on the north bank of the Potomac; also, in Augusta, Montgomery, Pulaski and Wythe counties, in central and south-western Virginia.

In the anthracite coal-fields outcrops of thin coal-beds have been found in the Pocono at a number of localities. The coal "blossoms" which have been found for many years on the Nesquehoning mountain in Carbon county, have encouraged many persons to explore for coal-beds having workable thickness and containing coal commercially valuable, but no such bed has ever been found. Along the escarpment of the North Mountain, in Luzerne, Columbia, and Lycoming counties, coal outcrops have been found in a number of localities in the Pocono Sandstone; these finds have been the basis for fabulous reports as to the discovery of new and valuable coal-fields.

In Pennsylvania the Pocono coal-beds have never been found having workable dimensions or containing coal sufficiently pure to be economically mined except along Tipton run. On account of the exceptional occurrence in this locality, the commercial value of the area along the run, where the beds have been opened, cannot be established simply by geological evidence, since all the known facts

relating to the geology of No. X would not warrant a practical conclusion, that any coal-beds which it contains might be expected to be persistent in thickness, or made up of coal of any great purity, over an extended area. The facts, however, are not sufficient to warrant an assertion that *No. X coal-beds cannot be found having a persistent minable thickness*, and containing *coal commercially valuable.*

That the Tipton Run coal-beds, as far as developments have been made, are of dimensions which will permit of their being economically mined and that the coal which they contain will bear a favorable comparison to the coal mined from *some* of the coal-beds of the Lower Productive Coal Measures, in the counties west of the Allegheny mountains, cannot be denied, as the facts stated below will prove. That these coal-beds can be depended upon, being persistent in thickness, and quality, over extended areas, actual exploration and mining can alone prove.

The geological horizon of the Tipton Run coal-beds has been universally assigned to the Pocono Sandstone, No. X, by all the professional geologists who have made examinations of this part of Blair county for the past thirty years.

It has been recently suggested that the Tipton Run coal measures were the easternmost extension of the Clearfield county coal measures, and that a fault exists along the escarpment of the Allegheny mountain which has permitted of the downthrow of all the strata on the east side of the fault, bringing the Clearfield county coal measure strata into the foot hills along the face of the Allegheny mountain, where the Tipton Run coal-beds are found.

There are many significant facts, which can be obtained by any geologist on the ground, which will easily disprove any such hypothesis.

The geological structure all along the frontier of the Allegheny mountain is so simple, and is so clearly defined in the county reports, published by the Survey, that it is unnecessary, in this place, to enter into any discussion as to the validity of such an hypothesis. One fact may, however, be stated, which of itself *absolutely disproves* such

an hypothesis. The rocks in which the Tipton Run coal-beds are found all dip towards the north-west. To the east, and beneath them, occur bold outcrops of red sandstones and shales, and to the west, and above them, occur similar outcrops; the outcrops in the first instance must be the Catskill Red Shales and Sandstones, No. IX, and in the second instance, the Mauch Chunk Red Shales and Sandstones, No. XI, and the sandstone series in which the Tipton coal-beds are found must belong to the Pocono formation No. X, since this is the only formation in the Palæozoic column in Pennsylvania which is both underlaid and overlaid by a red shale and sandstone formation.

The Pottsville Conglomerate, No. XII, the Mauch Chunk Red Shale, No. XI, the Pocono Sandstone, No. X, the Catskill Red Sandstone, No. IX, with their immediately underlying group of rocks, forming formations No. VIII and VII, are exposed to view in the numerous ravines which descend from the Allegheny mountains into the headwaters of the Juniata river, back of Tyrone city, Altoona, and Hollidaysburg. Along these ravines, these formations have been repeatedly measured by a number of geologists. Three of these sections, which have been made out in great detail, have been measured from the Coal Measures, formation No. XIII, down to the Trenton Limestone, formation No. II, around Bellefonte, and near by Altoona and Lock Haven. The nearest detail section to Tipton run was measured by Mr. R. H. Sanders, and the results of his measurements have been published in report (T) on Blair county.

The Pennsylvania Railroad tunnel, through the crest of the Allegheny mountains, at an elevation of 2126 above tide, goes through the Upper Freeport coal-bed, which at this point is 5½ feet thick, and has a western dip of 1°, the knobs along the summit above the tunnel being immediately capped by the Mahoning sandstone.

Descending the Allegheny mountain along the Pennsylvania Railroad from the Summit tunnel down to Altoona, the following formations: Lower Productive Coal Measures, No. XIII; Pottsville Conglomerate, No. XII; Mauch Chunk Red Shale, No. XI; Pocono Sandstone, No. X;

Catskill Red Shale, No. IX; Chemung, Portage and Hamilton Shales, Sandstones and Slates, No. VIII, are successively passed through.

All these strata have a dip toward the north-west, ranging from 1° at the Summit tunnel, as a minimum, to 55° at Altoona, as a maximum. The dip at the base of the conglomerate is 10°; at the base of No. X, in the center of the great Horse Shoe Curve, 18°; at the base of No. IX, 32°, all being toward the north-west.

The thicknesses of these formations, as measured by Mr. Sanders along this line, are as follows: No. XIII, Lower Productive Coal Measures, 345′; No. XII, Pottsville Conglomerate, 223′; No. XI, Mauch Chunk Red Shale, 283′; No. X, Pocono Sandstone, 1241′; No. IX, Catskill Red Sandstone, 2560′; and No. VIII, Chemung, etc., 6519′.

The Tipton Run openings occupy the same geological position in formation No. X as the strata which underlie the surface of the ground near the level of the Horse Shoe Curve on the Pennsylvania Railroad. The coal openings occur about nine miles, in an air line, north 25° east of the railroad curve.

The dip of the Carboniferous and Devonian measures above referred to, from Bear Pen Point on the top of the Allegheny mountains, down Tipton run, past the coal openings, is toward the north-west, in the same direction as the dips along the line of the Pennsylvania Railroad. The degree of dip is, however, not quite as great as in the latter locality. Along the top of the Allegheny mountain, in the vicinity of Bear Pen Point, the strata have about the same dip toward the north-west as in the vicinity of the Summit tunnel; but the dip of the Pocono Sandstone, in the vicinity of the coal openings, is only 12°; whereas, at the Horse Shoe Bend, it averages about 18°, although at one point, at the north end of the curve the No. X strata have a dip of 31°, which dip, however, is evidently purely local.

No detail section showing the individual thicknesses of the Lower Productive Coal Measures west of Bear Pen Point has been measured.

The Pottsville Conglomerate, No. XII, and Mauch Chunk

Red Shale, No. XI, below Bear Pen Point; the Pocono Sandstone, No. X, in the vicinity of the Tipton Run coal openings; and Catskill Red Shales and Sandstones, No. IX, which are boldly exposed along Tipton run below the coal openings, have not been separately measured; but, the total thicknesses, of the individual strata of each formation, have been estimated and found to agree with the thicknesses of the same formations as determined instrumentally, in detail, by Mr. Sanders.

The summit of Bear Pen Point is apparently capped by the upper part of the Pottsville Conglomerate; 225′ below the summit occurs an outcrop of flaggy sandstone, the individual layers of which vary from 1″ to 2″ in thickness. Immediately below and in the vicinity of this outcrop there were found fragments of red shale in the soil, and the outcrop itself was taken to represent the bottom of No. XII.

Mr. William Foster reports an outcrop of black limestone on the slope of the mountain below Bear Pen Point. Mr. C. S. d'Invilliers visited this limestone and reported its thickness as 10′ and its elevation as 300′ below the summit of the point. Mr. Foster was unable to find the outcrop during my cursory examination of the property, but from specimens which I examined, and from its position in the measures, it is unquestionably the outcrop of one of the limestone beds so frequently found in the upper part of the Mauch Chunk Red Shale, No. XI. Bear Pen Point is a little over a mile (5700′) N. 60° W. of the Loup Run opening; the elevation of the point is 2382′, and the elevation of the opening is 1370′.

The relative stratigraphical positions of the several coal-beds opened at the different openings along Tipton run is a matter of prime importance. In order to ascertain the exact relationship of these beds a careful geological and topographical survey in the vicinity of all of the openings would be required. I have determined sufficient facts, however, which, when taken in conjunction with the surveys made for the Pennsylvania Railroad by Mr. C. S. d'Invilliers, have enabled me to determine, beyond all doubt, the *general re-*

lationship of the beds, without ascertaining the *exact thickness* of the rocks between any two successive beds.

Ascending the hill, on the west side of Loop run, from the Saw Mill dam, the first prospect coal opening is found at an elevation of 1335 feet. At this opening scattered seams of coal were found in a rock interval of six feet, the largest bench of coal being 18 inches.

At the second opening further up the run, but at the same elevation as the first, a bench of coal 2 feet thick is reported, overlaid by an argillaceous sandstone, above which the top coal-bench was found. Neither the thickness of the sandstone or of the top bench coal were reported.

At the third opening, at about the same elevation as the other two, 3 feet of solid coal were reported, with a fire-clay floor.

At the fourth opening the elevation is 1350 feet, and at this point 2 feet 4 inches of coal were reported. The latter bed is underlaid by a heavy gray fire-clay.* The direction and distance of this fourth opening, from the mouth of Loop run, I did not determine; so that, it is impossible for me to make an estimate of the thickness of the included strata. Mr. d'Invilliers, however, reports the following section:

Coal-bed C, (Loop Run opening,)	3′	6″
Interval,	25′	
Coal-bed B,	2′	4″
Interval,	25′	
Coal-bed A,	3′	
Interval,	30′	
Coal-bed, No. 2,	1′	6″
Interval,	20′	
Coal-bed, No. 1, (Largest bench,)	1′	6″

The coal-bed opened at the Loop Run drift has been commonly known as bed "C." The face of the drift is about 700 feet from the mouth of the gangway, having a general direction along the strike of the bed of north 15°

*These facts were reported to me by Mr. Titus S. Emery, President, Mr. C. B. Finley, Mining Engineer, T. R. C. Co., and Mr. William Foster, who superintended the explorations on the ground. The depth below the surface of the ground at which coal was found at each point was not reported.

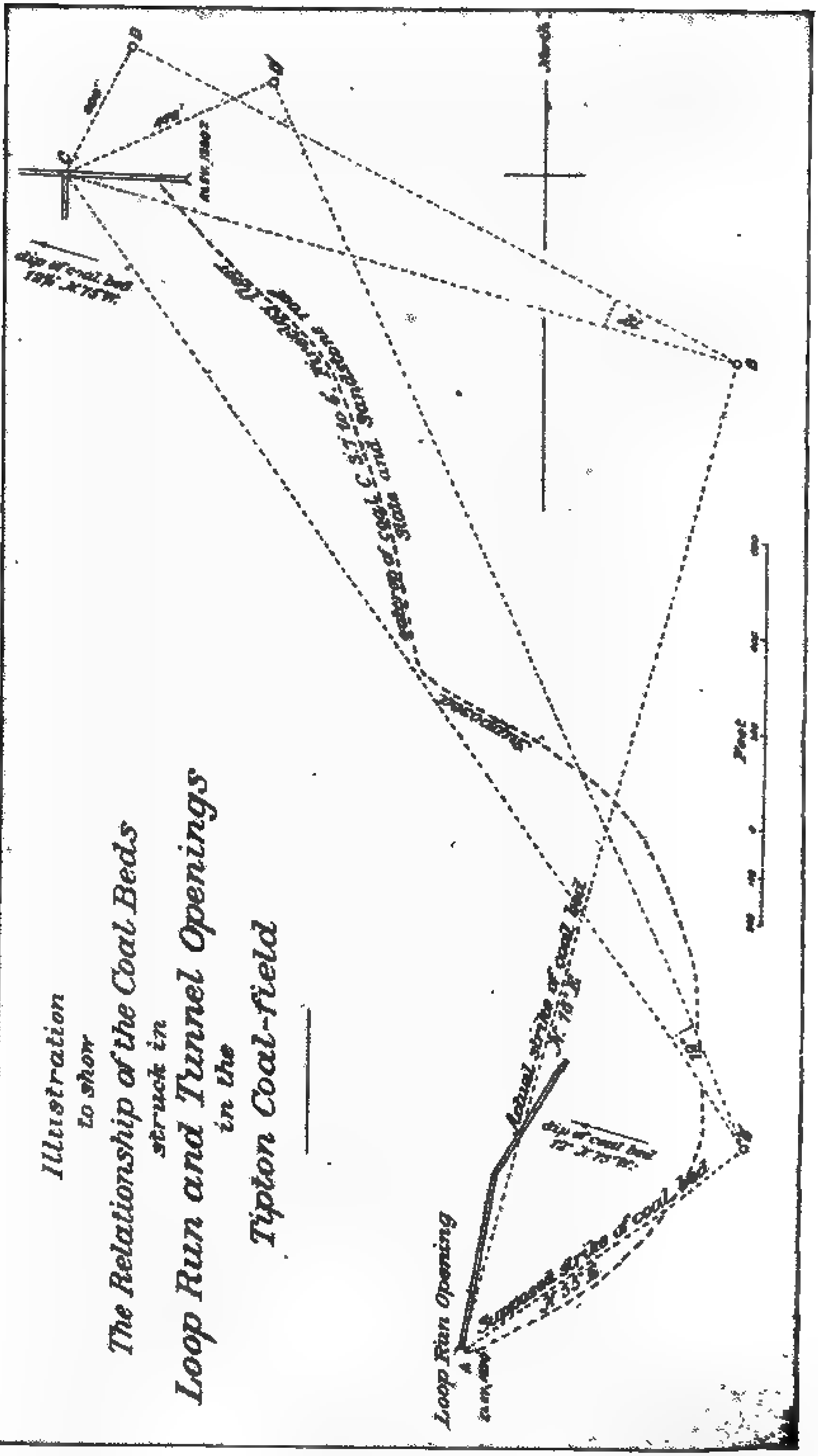


Illustration
to show
The Relationship of the Coal Beds
struck in
Loop Run and Tunnel Openings
in the
Tipton Coal-field
Loop Run Opening
Actual strike of coal bed
Supposed strike of coal bed
Slate and Sandstone roof
Feet
North

east. The position of the drift is shown on the accompanying map and the plate on page 260.

A cross-heading has been driven to the right of the gangway for a distance of about 250 feet, and in a general direction of north 50° east. The dip of the bed was measured at several points in the opening and found to be 12° north 75° west. The section of the bed measured as follows:

Argillaceous slate, slightly ferruginous,	—	—
Top *coal* bench,	2′	7″
Slate,		2″
Bottom *coal* bench,	1′	1″
Fire-clay floor,	—	—

The slate between the two coal benches contains considerable sulphur.

At the face of the main gangway the following section was measured:

Slate roof,	—	—
Top *coal* bench,	2′	4″
Slate,		2″
Bottom *coal* bench,	1′	
Fire-clay floor,	—	—

When this drift was visited, August 27, 1885, it had stopped at a fault, the direction of which was south 50° east and north 50° west.

At a point 30 feet vertically below the bottom of the Loop Run opening, a drift has been driven into the face of what is probably the representative of bed B in the section just referred to. Near the mouth of the drift a section was measured, as follows:

Slate,	2′	
Top *coal* bench,	2′	
Slate,		1″
Bottom *coal* bench,	1′	1″
Hard, sandy fire-clay floor.		

As far as this bed has been tested it varies much in thickness, but no rock fault has been found.

On the west bank of Tipton run, north of Loop Run opening, a tunnel has been driven in a direction north 87° 15′ west, for a distance of about 350 feet. Up to August, 1885, his tunnel had cut two beds of coal.

In the second bed struck in the tunnel, at a distance of about 250 feet from the mouth of the tunnel, a gangway was driven to the south for a distance of about 100 feet. This coal-bed dips 12° in a direction north 75° west. On account of the thickness of this bed and the general appearance of the coal, it had been considered, by those who had made examinations of the tunnel, prior to my examination in August, 1885, identical with the bed opened in the Loop Run drift.

I have determined, that between the second bed opened in the tunnel and between the bed opened in Loop Run drift, there are at least 300 feet of strata. This is clearly demonstrated by the geometrical construction on the accompanying plate page 260. The degree and direction of dip at the drift and at the tunnel are the same, so that it is reasonable to suppose that there is no change of dip between these two points. The actual strike of the coal-bed between the drift and tunnel would be represented by line AB, the dip of 12° being represented by the angle CBD; the line CD being drawn perpendicular to the line BD, and which scales 300 feet, represents the distance which the coal-bed opened in the Loop Run opening would be underneath the second bed struck in the tunnel, the distance of 300 feet being along a line perpendicular to the dip of the strata.

On the map obtained from the Summit Coal Company, the strike of the coal-bed is represented by a line paralle to the line AB′, which has a direction north 55° east, and the outcrop of the coal between the drift and the tunnel is represented by the dotted line on the accompanying page plate. These two statements are conflicting, since if the strike of the beds is as represented, the bed opened in the Loop Run drift would be at least 478 feet below the second bed struck in the tunnel, as represented by line CD′ on the accompanying illustration.

The bed opened in the Gates drift, on the east bank of Tipton run north of the tunnel, is probably the same as the second bed struck in the tunnel. A section of this bed at the face of the drift, in August, 1885, was as follows:

Top *coal* bench,	2′ 6″
Bony slate,	1″
Bottom *coal* bench,	1′ 8″
Fire-clay floor.	

This bed had a dip at the face of the drift of 27° in a direction south 60° west. This dip is unquestionably abnormal and purely local.

North of the Gates drift several coal-beds have been opened, the positions of three of which are shown on the map accompanying this report.

The coal at the first opening, immediately north of the drift, is reported 2 feet thick. Between this bed and the Gates drift bed there is about 25 feet of strata.

At the second opening, the bed has been reported 2 feet 8 inches thick, and at the third opening, 3 feet thick. The thickness of strata between the first and second openings is probably 40 feet, and between the second and third, 45 feet.

A little over a quarter of a mile north of the Gates drift, according to the map constructed by Mr. C. S. d'Invilliers, two beds have been opened by drifts on the east side of Tipton run. According to Mr. Titus S. Emery, President of the Tipton Run Coal Company, one of these drifts is the old Kramer and Hart, Laurel Run coal bank. This opening was examined by Mr. Franklin Platt, in 1879, and reported on as follows: *

"The coal-bed is thirty inches thick, with six inches of bone coal, the entire three feet being mined.

"The roof consists of 10 feet of black and gray slates, very loose, rendering extensive timbering necessary in the mine.

"The floor is six to twelve inches of fire-clay, which probably rests on sandstone, though the latter was not seen.

"Five hundred feet south of the coal mine there is a coal outcrop at the water's edge, fully 15 feet below the level of the mine. There formerly was a mine on this second outcrop, but the common report is that the miners struck a wall of rock. There may be a small downthrow in the measures on the mountain face at this point, but it is more

*Report T, page 25.

probably an irregularity in the coal deposit, and the two outcrops may really belong to one coal-bed.

"Such irregularities are constantly found in the small and treacherous coals of the Pocono formation. At the Kramer & Hart mine the opening is about 8 feet above the run, but on tracing the bed along the outcrop, the coal shows only a few inches in thickness when it reaches the run level, and this small coal streak is underlaid and overlaid by slates of the same kind as are seen in the roof of the mine. The distance is short, the outcrop visible the entire distance, and yet the coal-bed has been almost entirely replaced by slates.

"The *character* of the coal is bituminous. A specimen of it from the Kramer & Hart mine was analyzed by Mr. McCreath, who reports the results thus:

"Bituminous coal, with a bright shining luster, somewhat coated with silt, and containing considerable iron pyrites.

Water at 225°,	.700
Volatile matter,	26.790
Fixed carbon,	66.878
Sulphur,	.802
Ash,	4.830
	100.000
Coke per cent.,	72.510

"The coal forms a coherent coke with a silvery luster, and yields a gray ash with a red tinge.

"The fuel ratio is, volatile hydrocarbon to fixed carbon as 1 : 2.496.

"*Pocono* (*Vespertine*) *coal* has not been opened at any other place along the mountain face in Blair county. As no coal-bed of *workable* size has ever been seen in this formation in any part of Pennsylvania, although (as at Duncannon, on the Susquehanna River,) thin coal-beds do exist in it, it is not expected that the ravines of the Allegheny mountain will ever be valuable in this respect."

On March 8, 1886, Mr. Emery sent me, at my request, a sample of the coal, which, according to his letter, was "taken from the left-hand heading in the tunnel on Tipton run, about 60 yards in from the turnout from the main

heading, that turnout being 92 yards from the mouth of the tunnel."

This coal has been analyzed by Mr. McCreath, with the following results:

Water at 212° F.,	.584
Volatile matter,	29.426
Fixed carbon,	58.041
Sulphur,	3.159
Ash,	8.790
	100.000
Fuel ratio,	69.99
Color of ash,	pinkish gray.

Mr. McCreath, in commenting on the character of this coal says:—"The sulphur exists for the most part as iron pyrites, in thin partings throughout the coal. Duplicate tests show 3.154 and 3.164 per cent. of sulphur—with an average as above."

The commercial value of the Tipton Run coal-beds will depend; first, upon the persistency of their thickness; second, upon the quality of the coal which they will be found to contain. These two facts will have to be determined (1) by actual mining and (2) by the value of the coal as a fuel determined by practical tests.

As to the first question; it has been ascertained, in the Loop Run drift, that the bed maintains a workable thickness between 3½ feet and 4 feet thick for a distance along the main gangway, or the strike of the coal-bed, for over 700 feet, and for a distance up the dip of the coal-bed, to the left of the main gangway, for 250 feet. The upper bed, which has been opened in the tunnel and the Gates drift, has been tested as to persistency of thickness to about the same extent as the bed in the Loop Run opening.

As to the character and quality of the coal from two of the beds, the composition of selected samples is shown by the two analyses already given.

In order to ascertain the fuel value of the coal, mined from the Loop Run drift, several tons were shipped to the Pennsylvania Railroad Company, and practical tests made. By the courtesy of Mr. J. N. Dubarry, Third Vice-President of the Pennsylvania Railroad Company, I am permitted to

quote from the reports made in April and June, 1883, to Mr. Theodore N. Ely, General Superintendent of Motive Power, by Mr. John W. Cloud and Mr. Samuel Porcher:

Extract from April report.

"We have tried the car load of coal sent by Mr. Titus Emery, from mines about four (4) miles back of Tipton Station. Enclosed please find a report of the trial, made out by Mr. Samuel Porcher, who followed up the trial.

"As the coal did very well on the Eastern Slope, I think it would be advisable to order two (2) car loads more, one to be tried on through runs, and one for use on the engines around the yard.

"One car load of this coal was used up on the two engines—Class 'I' engines, 411 and 571, Pittsburgh Division—which are the Eastern Slope helpers. After one trip each, both engines were laid up four days, and put in first-class order, flues cleaned, new arches put in, etc., so that throughout the greater part of the trial everything was favorable for the coal. Under these circumstances the engines steamed excellently. On one occasion the pressure on engine 411 fell to 110 pounds, the only time the gauge of either engine registered less than 118 pounds. The coal burnt freely, but was fine and quite light, and did not coke well, thus making it very difficult to build up a fire that had gotten into a bad condition. This was the cause of the fall of pressure on engine 411, but even then the loss was not continual and entirely beyond control.

"The coal seemed remarkably free from clinker, but formed a large amount of dark colored ashes and cinders. The smoke boxes did not collect a larger amount of 'sparks' than usual. It is harder and not so fine as the coal from the Great Bend mine on the Bell's Gap Railroad. It also appears to make a less heavy black smoke than the ordinarily furnished coal, because it probably contains a smaller per cent. of bituminous matter. During the trial the weather was dry and snow on the ground.

"About six wheel-barrow loads of this coal were used in the blacksmith's shop on two heavy fires, (welding pedestal

legs to frames and shaping draw-heads). As taken from the car, between 50 per cent. and 75 per cent. of the coal passed through the screen. The men using it said it was clean and freer from clinker than they usually got; that it would make a hollow fire, and that they could use it for this work, but it was somewhat light; that is, was blown away by the draught, and did not make very solid coke, upon the formation of which they depended. They did not find in it a larger quantity of sulphur than usual. Taking this coal both on the engines and in the smith-shop, it gave fair results.

Extract from June report.

"We have just finished a trial of two car loads of coal from near Tipton, Emery's mines; one car load on Class 'I' engine, No. 152, running between Altoona and Derry, and the other under the four low-pressure boilers in machine-shop yard.

"On engine No. 152 the coal made a good deal of ash, but fire was free from large clinkers; steam averaged 120 pounds pressure. As the coal is very light it makes a fire that is hard to keep solid, and is apt to work into holes when the engine is working hard. The engine consumed rather more of this coal per trip than of the coal ordinarily used.

"Under the shop-boilers the coal burned well when fires were first started, but toward evening the fires got very dirty and did not do so well.

"We think, however, that we could use some of this coal, if the mines are sufficiently developed to furnish it to us at competing prices."

I understand that the coal, of which the above tests were made, was mined from the Loop Run drift; no analysis of the coal-bed worked in this drift has been reported.

A number of analyses * were made, by Mr. McCreath, of specimens of Pocono coal taken from the opening on Cove mountain, near Duncannon, Perry county, and from the

* Report MM, page 100.

beds cut by the Sideling Hill tunnel, on the East Broad Top Railroad, to both of which localities reference has already been made. These analyses show so much ash, ranging from 14.39 per cent. in bed No. 10 of the Sideling Hill section (see page 252) to 39.44 per cent. in one of the specimens from Cove mountain, that if the coal-beds in these two localities were thick enough, which they are not, to be economically mined, the coal would be too impure to be economically burned.

Numerous analyses * of Pocono coal, from the Virginia counties already mentioned, show the fixed carbon ranging from 49 to 76 per cent., the volatile matter from 9 to 13 per cent., the ash from 12 to 40 per cent., and the sulphur from .5 to 1.5 per cent. These fact are merely stated for comparison.

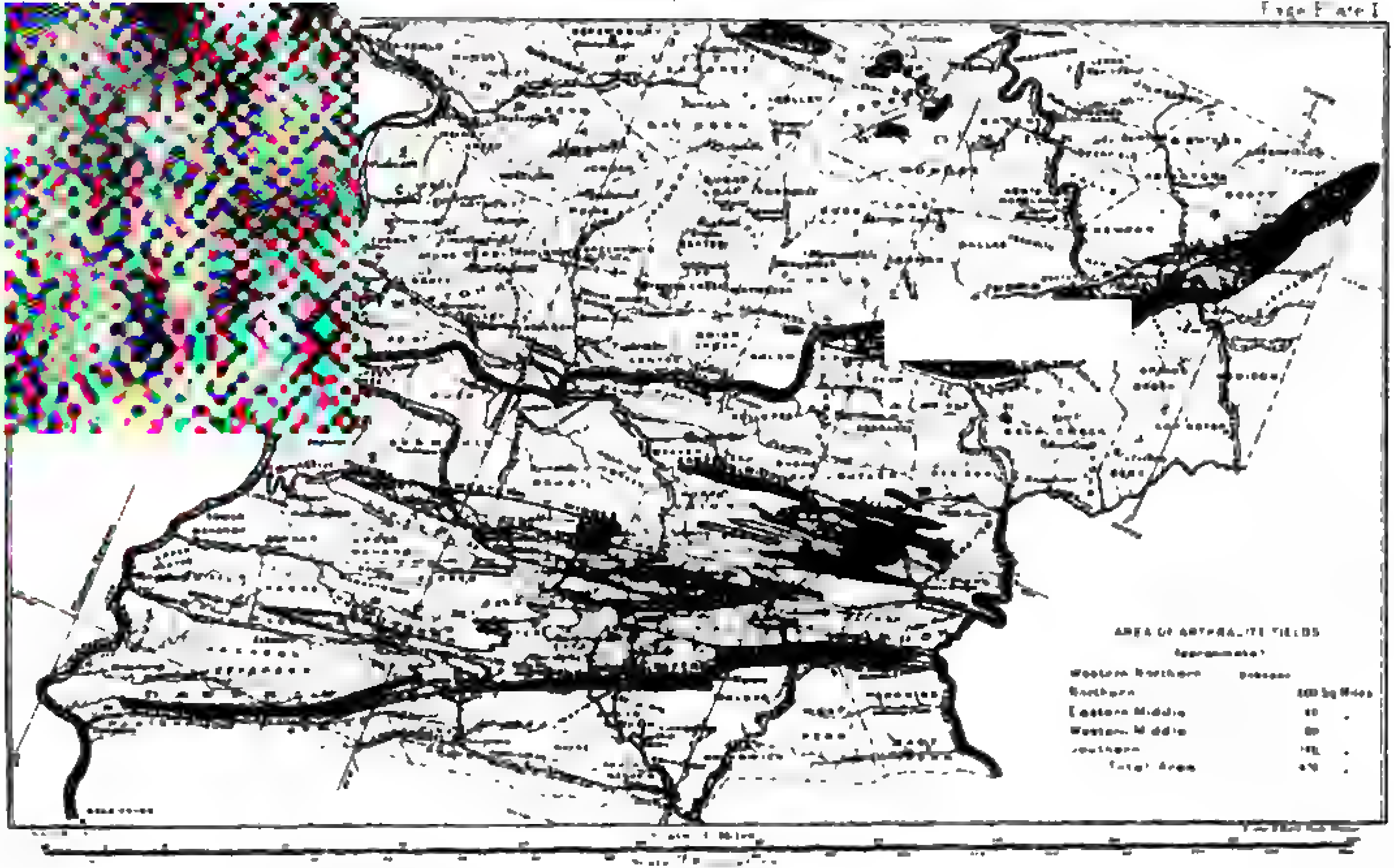
From explorations so far made, the purest coal, found in the Pocono Sandstone No. X, is that taken from the Tipton Run openings.

---

* **Mineral Wealth of Virginia, page 180.**

SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA

ANTHRACITE DISTRICT



Second Report of Progress in the Anthracite Coal-Regions.

*Part II.**

BY CHARLES A. ASHBURNER.

CHAPTER I.

General Description of the Anthracite Coal-fields.

1. Introduction.

The First Report of Progress of the Survey in the Anthracite District was made November 1, 1883, and included a general outline of the plan which had been adopted for carrying on the survey in the coal-basins, with a summary statement of the results of the Survey from the date of the commencement of the work in August, 1880, to November, 1883.

The only portion of the field, in which the work of the Survey had been completed up to that time, was that embraced within the Panther Creek valley, forming the eastern end of the Pottsville or Southern Coal-field, and lying between Mauch Chunk on the Lehigh river, and Tamaqua on the east branch of the Schuylkill river. The Survey sheets relating to this coal-basin have been published in the atlas of the Southern Anthracite Field, Vol. I; the First Report of Progress is largely descriptive of the geology and mining features of the area to which these atlas sheets relate.

The general plan for carrying on the survey of the anthracite region, which has been referred to in that report, has met with the favor of the prominent mining engineers throughout the region; and, after a test of five years, has

NOTE.—The principal l calities referred to in this report are indicated on the page map accompanying the Anthracite Report as page plate I.

*** Part I of this report was published in June, 1884, and contains the Statistics of Production and Shipment of Coal from the Anthracite Region for 1883 and 1884; it is accompanied by a general map of the coal-fie ds.**

been found to be amply sufficient to meet all the practical requirements which could reasonably be made of a State Survey. Although the general plan of survey has not been changed, yet increasing demands made by the owners and operators of coal lands, for immediate results in special areas, together with diminished annual appropriations on the part of the State for continuing the Geological Survey, have made it necessary to modify some of the details connected with the practical execution of that plan.

At the time of the publication of the First Report, it was expected that the future reports would be published simultaneously with the Survey atlases, containing maps and sections relating to definite areas, and that the reports would severally be specially descriptive of the respective areas to which the individual atlas sheets referred. (See the first report, page 5.)

The greatest practical demand, in the region, has been for the publication of accurate maps and sections, which should contain in a graphical form the conclusions relating to the structural geology of the coal-basins and the extent of mining, arrived at by the Survey; little interest being manifested, by practical men, in the publication of the text of the reports, other than as it might be needed to supplement the atlas sheets, by such explanations as might make the information contained on the sheets better understood.

Recognizing the importance of satisfying these public wants, the time of the different members of the Survey corps has been almost exclusively occupied by the field surveys, both on the surface and underground, and in addition only in such office work as was required for the publication of the maps and sections based on these surveys. This fact, together with a reduction in the size of the corps, required by smaller appropriations, has not permitted sufficient time for the preparation of reports descriptive of the sheets contained in the three atlases (Atlas, Northern Anthracite Field, Part I; Atlas, Eastern Middle Anthracite Field, Part I; Atlas, Western Middle Anthracite Field, Part I.) which have been published since the First Report of Progress and its accompanying atlas.

The policy, which has been adopted, of making the survey in the anthracite regions as thorough and as complete as it is possible, for any governmental survey to make it, consistent with a proper appreciation of the practical wants and of public economy, has unquestionably been a wise one.

The publication of reports, accompanied by maps, descriptive of the general geology of the region, similar to those which have been published in the distinctive agricultural and mountain districts of the State, where such reports have proved of great practical value, would be of much less worth to those citizens of the State having either individual or corporate interests connected with the mining of anthracite. Any geological work carried on in the anthracite region by the State, which should fail to give these citizens facts and information, that would aid them in the mining development of the coal-basins would be practically useless.

The extent of the State biennial appropriations, which are placed at the disposal of the Board of Commissioners, determines the extent of the work to be accomplished in the anthracite and other mining districts of the State, and not the character or thoroughness of the results.

In the early part of this year a map was prepared, showing the progress of the survey of the anthracite coal-fields, and upon it was outlined the areas where the surveys, essential for the accurate mapping of the geology of the respective districts, had been completed up to December, 1884. Since the preparation of this map, all the sheets which had been prepared by the Survey corps, relating to the special areas designated, have been published in four separate octavo atlases, already enumerated, so that the map represents the progress of the *completed surveys and publications* up to the close of the present year (1885).

The corps engaged in field work, during the past year, has been only one half in numbers of the corps engaged in similar work during the two previous years. The surveys have been very much extended beyond the limits of the areas outlined on the accompanying map, and the notes of these surveys are now being plotted, so that additional sheets will soon be ready for publication.

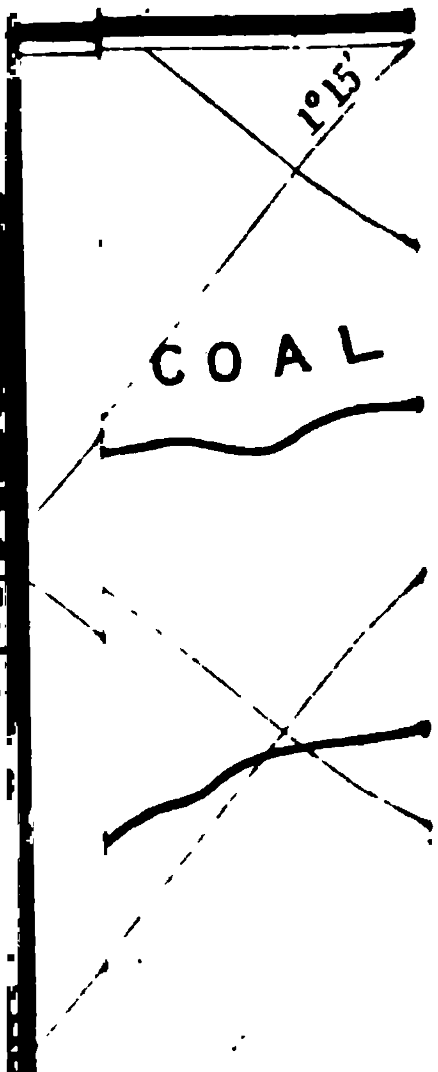
The progress of the work in the individual coal-fields is referred to in more detail further on. While later reference is made in this report to the four prominent sub-divisions of the region, the report is especially descriptive of that portion of the Northern Coal-field embraced by the six mine sheets outlined on the accompanying map; and, in addition, to a small area locally known as the Bernice coal-basin in the Loyalsock soft-anthracite field, which extends through portions of Sullivan and Wyoming counties.

The question has frequently been asked, in the anthracite region, how long will it take to complete the survey of that special district? The Survey management is as little prepared to give a practical or definite reply to this inquiry as any person in the region who is familiar with its geology and the extent of its mining operations. As the work of the Survey has progressed, and persons became more familiar with the character of the results attained, greater demands have been made upon the Survey corps for more detail work, either in areas which have not as yet been touched, or in areas where the surveys have been finished and sheets printed, but where a subsequent extension of the mining operations makes it desirable that the surveys should be extended, in order to take advantage of new and important facts which have been obtained relating to the geology of the coal-beds, in the new territory. So long as Pennsylvania keeps on producing annually over 30,000 tons of anthracite coal, which, if all gotton out of one ten-foot coal-bed in a horizontal position, would exhaust over two and one third square miles of new mining territory every year, there will be an increased demand for practical geological surveys.

This statement not only applies to the anthracite coal-fields, but to all districts of the State where mining operations are being actively prosecuted. It is specially applicable, however, to the anthracite region, since its coal-beds lie in all positions from a horizontal to a vertical one, and its geology is more complex, probably than that of any mining district, in the sedimentary strata of the United States.

The practical value of geological exploration, as an aid

G



T

ANT

to the most judicious and economical development of the coal-beds of the bituminous region, is of the greatest importance, but the geology in the bituminous coal-fields is easily understood in comparison to that in the anthracite region. In the former fields the coal-beds are generally horizontal, and when they dip are found to lie at angles seldom exceeding 4 or 5 degrees; the strata in such cases being thrown into gentle rolls, by broad and comparatively flat anticlinals and synclinals.

A glance at the accompanying map of progress shows the completion of the mapping of definite portions of each of the prominent anthracite fields.

In prosecuting the field operations, the original plan was to organize one field corps and commence the survey in the region where the greatest mining development had been attained, and to push the work progressively from this locality into the other coal-basins. The advantages which would have resulted from this plan would have been many; prominent among them, the economy consequent upon the employment of fewer geological experts and a greater number of assistants, occupying subordinate positions, under one expert field direction. In pursuance of this plan work was commenced in 1881 in the eastern end of the Southern Coal-field. As the field work progressed here, however, and persons in other districts, becoming cognizant of the advantages that would ensue from it, made demands for work elsewhere. These demands were so urgent that it became advisable that the work should not be temporarily confined to any one locality, but that the survey of the different prominent fields should be commenced and carried on simultaneously. This made it necessary for the corps to be broken up into several parties, placed in widely separated localities; the employment of an expert to direct each party naturally increased the expense of the work.

At the time of the publication of the last report, in the winter of 1883, four separate corps were at work in different sections of the region, under the personal direction of the geologist-in-charge; the first with Pottsville as head-quarters, the second with Hazleton as head-quarters, the third

with Wilkes Barre as head-quarters, and the fourth, a movable corps, which was sent to different sections of the region as the necessities of the work required. In consequence of this modified plan, the mapping of definite areas in each one of the four prominent fields has been completed; so that persons practically connected with the mining of anthracite, anywhere in the region, should, by this time, have become familiar with the character of the work which has been done, and be able to judge of its utility as a means for the more economical development of the coal-beds.

If the survey, in all of the coal-basins of the region, shall be brought up to the same state of completeness as that, in the Panther Creek district, to which Atlas Southern Anthracite Field, Vol. I, especially relates, it will probably demand as much time, in the future with the same corps at work as has already been required. If, the work is of such practical utility as is claimed for it by many practical men, it is a question which rests solely with the residents of the region, whether appropriations shall be made to permit of its continuance. The legitimate work of the Survey organization is to carry on the work in accordance with legislative acts, and not to see that sufficient appropriations are obtained. All that the Survey can be called upon to do, is to submit plans and estimates to the Legislature, and those citizens in the State, who are practically interested in the continuance of the work, should take such action as to insure the granting of necessary appropriations. This applies not only to the work in the anthracite region, but to that in all other districts of the State.

A complete general description of the anthracite region, geographical, historical, topographical, and geological, must necessarily be delayed until the survey of all the coal-fields has progressed sufficiently far, to permit of a description being made equally thorough for all districts. Such a representation will be embodied in a general report, of all the coal-basins, which it is proposed to publish after atlas sheets, similar to those already issued, shall have been constructed for all portions of the region. The general features of this

section of the State are so little understood, even by many mining engineers and geologists in the State, who have no special connection with or knowledge of the mining or geology of anthracite, that it seems desirable that a brief account of the region should be published, in this report of progress, in order to permit of a clearer understanding of the detail reports, relating to special areas, which will be published from time to time, with the several parts of the atlases.

2. *Geography.*

The anthracite region is situated in the north-eastern part of Pennsylvania, between the Washington meridian and that 1° 10′ east and the north parallels of 40° 25′ and 41° 40′.

It is divided into the following prominent divisions: (1) Southern or Pottsville field, extending from the Lehigh river at Mauch Chunk, south-west to within a few miles of the Susquehanna river, directly north of Harrisburg, and embraced by Carbon, Schuylkill, and Dauphin counties. The eastern end of this field, known as the Lower Lehigh or Panther Creek basin, between Tamaqua on the Little Schuylkill river and Mauch Chunk, has generally been included by the coal trade in the Lehigh field, from the fact that its coals resemble more closely the coals obtained in the Upper Lehigh region than those in the Pottsville field west of Tamaqua, and since the shipments from it to market have been largely made through the Lehigh valley. (2) Western Middle or Mahanoy and Shamokin field, lying between the eastern-most head-waters of the Little Schuylkill river and the Susquehanna river, and within Schuylkill, Columbia, and Northumberland counties. These two coal fields (1 and 2) are frequently designated in a general way as the Schuylkill region, although parts of them are better known to the trade by names defining districts from which coals of special characteristics are mined. (3) Eastern Middle, or Upper Lehigh field, lying between the Lehigh river and Catawissa creek and principally in Luzerne county, with limited areas extending into Carbon, Schuylkill, and Columbia counties. (4) Northern, or Wyoming and Lacka-

wanna field, lies in the two valleys from which it derives its geographical names, and is embraced almost entirely by Luzerne and Lackawanna counties. A small area in the extreme north-eastern end of the field extends into Wayne and Susquehanna counties. (5) Loyalsock and Mehoopany field,* lies within the area drained by the head-waters of the Loyalsock and Mehoopany creeks, and is contained in Sullivan and Wyoming counties. This field is from twenty to twenty-five miles north-west of the western end of the Northern field. Its geological structure resembles more closely that of the bituminous field, in which it has until recently been included, although the composition of many of its coals entitles them to rank with a number from the anthracite region.

The following table shows the present relative importance of the different counties, of the anthracite region, to the coal trade, by giving the number of tons, and percentage of coal produced in each county for the years 1883 and 1884.

Name of County.	1883.		1884.	
	Production. Tons.	Percentage.	Production. Tons.	Percentage.
Susquehanna, ...	30,945	0.09	77,(58	00.24
Lackawanna, ...	7,022,241	20.68	7,093,190	21.73
Luzerne, ...	14,176,487	41.75	13,382,912	41.00
Sullivan, ...	84,376	00.25	86,018	00.26
Carbon, ...	1,007,419	2.97	1,155,916	3.54
Schuylkill, ...	7,758,811	22.85	7,165,532	21.96
Columbia, ...	774,755	2.28	745,826	2.28
Northumberland, ...	2,497,801	7.36	2,331,108	7.14
Dauphin, ...	602,996	1.77	603,939	1.85
Totals, ...	33,955,831	100.00	32,641,499	100.00

The area of the region is about 1700 square miles. The natural geological and topographical boundaries of this area are formed by the mountains and ridges made by the Pocono Sandstone, No. X, although no workable coal-beds

*On the map of the anthracite region, this field has been called the Western Northern, in contradistinction to the Northern, Eastern Middle, Western Middle, and Southern fields.

have been found stratigraphically below the Pottsville Conglomerate, No. XII, the Lykens Valley or lowest anthracite beds being found in the latter formation. The greatest length of the region, from the north-eastern end of the Northern field to the south-western end of the Southern field, is about 115 miles, while the greatest width of the belt, containing the first four fields, is about 30 miles between Mauch Chunk and Shickshinny, near the western end of the Northern field.

The approximate areas underlaid by workable beds in the different fields, with the number of tons of coal mined from each field during 1883 and 1884, are shown in the following table:

FIELD.	Square miles, (approximate.)	1883—Tons.	1883—Percentage.	1884—Tons.	1884—Percentage.
Northern Field, . .	200	16,570,425	48.80	16,411,277	50.28
Eastern Middle Field,	40	5,586,397	16.45	5,098.684	15.62
Western Middle Field,	90	8,552,915	25.19	7,896,049	24.19
Southern Field, . . .	140	3,161,718	9.31	3,149.471	9.65
Loyalsock Field, . .	Unknown.	84,376	0.25	86,018	0.26
Total production, .	470 +	33,955,831	100.00	32,641,499	100.00

3. History.

The first record we have of the practical use of Pennsylvania anthracite is in 1768 and 1769, when it was employed for blacksmithing by two brothers named Gore, who had moved from Connecticut and settled in the Wyoming valley near Wilkes Barre. This was possibly twenty years subsequent to the commencement of coal mining in the United States, in the Mesozoic bituminous basin in the vicinity of Richmond, Virginia.

In 1775 it is reported that a cargo of coal was shipped in flat-boats from Wilkes Barre down the Susquehanna for the government armory at Carlisle.

The first organized effort for the mining of coal was in 1793, when the Lehigh Coal Mine Company was organized, and purchased land at Summit Hill, nine miles from Mauch Chunk, from Mr. J. Weiss. The Mammoth bed had been

accidentally discovered on this land in 1791. In 1803 this company loaded six flat-boats or river-arks, holding about 10 tons each, and started them down the Lehigh river for Philadelphia; only two of these boats reached destination. No one knew how to burn the stone coal and it was considered worthless. In 1814 another shipment of five arks was made in the same way, two of them reaching Philadelphia, the coal which they contained being sold to White & Hazard, at the Falls of the Schuylkill. This latter shipment was preceded two years (1812) by nine wagon loads of coal, hauled to Philadelphia from the Schuylkill region.

It appears that Judge Fell, of Wilkes-Barre, first used anthracite coal as a household fuel. In a memorandum dated February 11, 1808, he says: "Made the experiment of burning the common stone coal of the valley, in a grate, in a common fire-place in my house, and find it will answer the purpose of fuel, making a clearer and better fire at less expense than burning wood in the common way."

The first use of anthracite, in connection with the manufacture of iron, dates from 1812, when White & Hazard purchased one of the nine wagon loads from the Schuylkill region at the cost of transportation, and successfully used the coal in heating the furnace of their nail and wire mill at the Falls of the Schuylkill.

The regular shipment of anthracite coal to market, however, did not commence until 1820, during which year the Lehigh Coal and Navigation Company sent 365 tons from their famous mine at Summit Hill to Philadelphia.. In 1822 the Schuylkill region is reported to have first shipped to market 1480 tons. In 1829, 7000 tons were first shipped from the Wyoming region by the Delaware and Hudson Canal Company, whose canal had just been completed; the aggregate shipment from the entire region during the latter year being 112,083 tons.

Anthracite for the generation of steam was first employed in January, 1825, under the boiler of Thompson's rolling mill at Phœnixville.

The first successful use of anthracite as an exclusive fuel in the blast furnace was at the Pioneer furnace, built dur-

ing 1837 and 1838 at Pottsville, by William Lyman, of Boston. The first successful blast was blown in at this furnace on October 19, 1839. In recognition of the results obtained in this furnace, Mr. Lyman was paid a premium of $5000 by Nicholas Biddle and others, as being the first person in the United States who had made anthracite pig iron continuously for one hundred days. As early as 1824 attempts had been made to use anthracite in charcoal furnaces, mixed with charcoal. This and many subsequent attempts prior to 1839 seem to have all met with failure. On July 3, 1840, Mr. David Thomas successfully blew in a furnace which he had built for the Lehigh Crane Iron Company at Catasauqua, on the Lehigh river. Previous to this time Mr. Thomas had been associated with Mr. Crane in his experiments at Yniscedwin. The Catasauqua furnace was in active operation until 1879, when it was torn down.

The First Geological Survey of this region by the State was commenced in 1836, and was continued at intervals until the publication of the Final Report of the First Survey in 1858. The results of this Survey were in the highest sense valuable; they are being supplemented, rather than replaced, by the more detailed and practical work of the Second Survey.

The Second Survey was commenced in August, 1880, and has been vigorously prosecuted since that time. The principal object of this Survey has been to make the results practically useful to those directly interested in the exploration and exploitation of the coal-fields. About one third of the area of the region has been mapped by the Survey, although the work cannot be said to be one third completed, since the geology of the area not yet examined and surveyed is more difficult and less developed than that of the area already covered.

These few facts connected with the early history and development of anthracite coal are interesting when it is considered that the mining and transportation of Pennsylvania anthracite is the most important industry connected with the development of any mineral, in any one State, in the Union.

4. *Topography.*

The grand features of the topography of the region have been determined by its structural geology. These consist of two distinct series of ridges or mountains, one formed by the Pottsville Conglomerate, and the other by the Pocono Sandstone; and two series of valleys, that eroded out of the Coal Measures, surrounded by the Pottsville Conglomerate ridges, and that cut out of the Mauch Chunk Red Shale, No. XI, which lies between the two series of ridges. The Pottsville Conglomerate mountains rise from eight hundred to one thousand feet above their bases, while the Pocono mountains are generally, though not always, higher. The difference between the extremes of elevation within a radius of twenty-five miles rarely exceeds fifteen hundred feet, while that between the extremes within a compass of two or three miles seldom amounts to more than one thousand feet. In speaking of these grand features, Professor Lesley says: "Each coal-basin is set in a double frame, being limited by a mountain of conglomerate, outside of which runs a narrow valley or trough of red shale, outside of which again runs a second and still higher mountain of white sandstone, the outside flank of which is always furnished with a terrace of red sandstone." The surface of the valleys underlaid by the Coal Measures is undulated by small ridges, which are formed by the harder sandstones contained in the intervals between the coal-beds. The coal-beds themselves frequently form terraces along the slopes of the ridges, which permit of the coal-beds being easily traced, in many localities, over considerable areas. The most prominent of these ridges seldom rise to a height more than half of that of the enclosing Pottsville Conglomerate mountains. The Broad Mountain plateau, separating the Western Middle and Southern fields, and ranging about five miles wide and fifteen miles long, the Upper Lehigh Mountain plateau, containing the coal-basins of that region, and ranging about eight miles wide and fifteen to twenty miles long, and the Nescopec Mountain plateau, which crosses the Lehigh Valley and Lehigh and Susquehanna Railroads between White Haven and the southern rim of the

Wyoming Valley, are exceptions to the usual sharp profiles of the Pottsville and Pocono mountains. A general idea of the height of the region and surrounding areas above ocean level may be had from the following elevations of prominent points:

Harrisburg, (P. R. R. depot,) . .	**321**	**Tamaqua. (P. & R. R. R. depot,)**	**803**
Northumberland, ...	**452**	**Mahanoy City, ...**	**1243**
Catawi ssa, ...	**477**	**Shenandoah, ...**	**1252**
Shickshinny, ...	**521**	**Gilberton, (P. & R. R. R. depot,)**	**1133**
Nanticoke, . . .	**538**	**Ashland, ...**	**859**
Wilkes Barre. (L.&S. R. R depot,)	**550**	**Mount Carmel, ...**	**1054**
Pittston, (L. V. R. R. depot,) . .	**571**	**Shamokin, (P. & R. R. R. depot,)**	**738**
Scranton, (D. L. & W. R. R. depot,)	**739**	**Mauch Chunk, (L. V. R. R. depot,)**	**544**
Port Clinton, ...	**410**	**Hazleton, (L. V. R. R. depot,)**	**1612**
Schuylkill Haven, ...	**526**	**Drifton, (L. & S. R. R. depot,) .**	**1633**
Pottsville, ...	**614**	**White Haven, (L. V. R. R. depot,)**	**1148**
Tremont, ...	**766**	**Upper Lehigh, ...**	**1802**

5. *Structural Geology.*

All the rocks found in or immediately surrounding the anthracite region are sedimentary, belong to the Palæozoic Era, and are highly corrugated. These strata, which after their deposition were comparatively horizontal, have been thrown into the deformations, in which we now find them, by the secular cooling and consequent contraction of the earth's surface, after the close of the Palæozoic Time. The prominent features in the structure of this portion of the State are illustrated by the accompanying vertical cross-section (Fig. 1.)

Fig. 1.

The denudation of the surface of the region by the natural eroding agents, which are still at work in a greater or less degree, has been very great, after the strata was upheaved and corrugated. From the top of Kittatinny mountain has been cut away all the strata included between the Medina Sandstone (part of formation No. IV) and the highest coal measures (part of No. XIII) in the of Panther Creek basin, measuring in the aggregate over 18,000 feet, perpendicular to the bedding. If the dip of the strata, after the corrugation was effected and before denudation had perceptibly taken place, was the same along a vertical line through the mountain as it is now, then as much as four miles vertical thickness of strata have been eroded from the area now marked by the Kittatinny crest. This mountain is one of the boldest topographical features in the State. It extends from the Delaware Water Gap, between New Jersey and Pennsylvania, south-west for 90 miles to a point in Franklin county twelve miles west of Chambersburg. The details of the structure between that portion of the mountain* included between the Lehigh and Susquehanna rivers and Sharp mountain, formed by the Pottsville Conglomerate, No. XII, which skirts the south-eastern limit of the Southern Field, is different in many places from that shown in the accompanying section; the general structure, however, varies little.

The northern end of the section through the Panther Creek coal-basin has been enlarged (from scale of 3 miles to 1 inch, $\frac{1}{190080}$th of nature to a scale of 800 feet to 1 inch, $\frac{1}{9600}$th of nature) to illustrate some of the details of the structure of the anthracite basins (Fig. 2.)†

*Approximately defined by the lower border line of the accompanying map of the anthracite coal-fields, page plate I.

†The method which has been used for representing the coal-beds and rock strata in this section is that which has been proposed by the author for all of the cross sections of the Geological Survey, as follows: (1) Where a coal-bed has been worked out in the plane of section it is shown by two lines, one at the top and the other at the bottom of the bed; (2) where the position of a coal-bed is certainly known, but the coal has not been worked out in the plane of section, it is shown by a heavy black line; (3) where the position of a coal-bed can only be approximately determined, with present available facts, it is indicated by

Fig. 2.

The Pottsville Conglomerate, (No. XII,) underlying the Productive Coal Measures, has been thrown into broad, regular, and generally symmetrical flexures, while the overlying softer measures, containing all the workable coals, except in those districts where the Lykens Valley beds have dimensions sufficient to be mined, are found conformable to subordinate flexures of three kinds: symmetrical (central anticlinal, Fig. 2,) unsymmetrical (southern anticlinal,) and reversed (northern isoclinal.)* In the case of the unsymmetrical and reversed flexures, the plane passing through the axes of the flexures, as exhibited in the different strata, is generally inclined down and toward the area of maximum disturbance.

This area of maximum disturbance lies to the south-east of the anthracite region, in the vicinity of Kittatinny mountain, and is co-extensive with it throughout the central part of the State, crossed not only by this Medina crest, but by the parallel mountains capped by the same formation, and constituting what are known as the Blue ridges† in Penn-

---

a single line representing the bottom of the bed; (4) the rock strata are only shaded where their character is absolutely known. One of the primary objects of the Anthracite Survey has been to render the results of its work of practical utility, and this method of constructing the cross sections renders them of the greatest value to those superintending the mining of coal.

*Through the region an isoclinal, or a flexure, where the strata appear to dip in one direction on either side of the axis, is generally called an overturn or overturned anticlinal.

†The structure of these mountains and ridges is illustrated by numerous cross sections constructed by the author in 1874 and 1875, and contained in Report F.

sylvania and the North mountains in Virginia. This inclining of the unsymmetrical and reversed flextures toward the north and north-west was formerly thought to be universal in the anthracite region ; recently, however, a number of exceptions have been found in small anticlinals and isoclines, which incline toward the south and south-east. In the case of the accompanying sections, the Lehighton anticlinal (Fig. 1) and Panther Creek isoclinal (Fig. 2) follow the *general law* of inclination.

The area of maximum folding and contortion of the coal bearing measures is in the Southern field, where the occurrence of isoclinals and sharp, narrow anticlinals and synclinals is more frequent. In other fields the flexures gradually become flatter, broader, and further apart toward the north-west. The structure in the Eastern Middle field is an apparent exception; when it is remembered, however, that in this district the flexures in the coal measures are found at a much greater height above ocean level, and the coal-basins are generally much shallower than in the Southern field, the general conclusion holds true, for the most complicated structure is invariably found in the bottoms of the coal-basins, where the squeezing of the strata was the greatest during the original plication.*

The Northern field, which is further removed from the area of maximum disturbance, is composed of a broad, canoe-shaped basin with moderate dips, the surface of any one of the coal measure strata, in general, being but slightly undulated by broad, low anticlinals and shallow synclinals, while the structure of the Loyalsock and Mehoopany field,† which is still further removed, is identical with that of the Pennsylvania bituminous field ; the average maximum dips

*The difficulties which have been encountered in mining near and in the bottoms of the Lehigh basins, foreshadow the greater irregularities of structure, which will probably be met with in mining in the bottoms of the Southern field basins. Although the details of structure are rarely duplicated in different districts, yet I believe a careful mapping and study of the structural geology of the Lehigh basins will aid materially in the most economical development of the deeper portions of Southern field basins.

†This field has been provisionally named, on the map, the Western Northern.

of the coal-bed ranging from between 3 and 5 feet to 100 feet.

Some idea may be had, from the following table, of the depths of some of the anthracite basins in which information has been obtained, of a sufficiently definite character, to permit of estimates being made. The elevations are given in feet above ocean level:

Northern Field, Wilkes Barre Basin.

	Feet.
Wilkes Barre, (L. V. R. R. depot,)	+549
Mammoth bed outcrop on north side of basin, at Kingston Coal Company's slope, No. 2,	+788
Mammoth bed outcrop on south side of basin, at Hollenback slope, No. 2,	+774
Bottom of Mammoth bed basin under flat, north of Wilkes Barre, (estimated,)	—800*
Width of basin, 23,200 feet (4.4 miles.)	

Eastern Middle Field.

Drifton Basin.

Drifton, (L. & S. R. R. depot,)	+1633
Buck Mountain bed outcrop on north side of basin, at Drifton slope, No. 2,	+1692
Buck Mountain bed outcrop on south side of basin,	+1645
Bottom of Buck Mountain bed basin,	+1150
Width of basin, 2,250 feet (.4 miles.)	

Hazleton Basin.

Hazleton, (L. V. R. R. depot,)	+1612
Mammoth bed outcrop on north side of basin,	+1660
Mammoth bed outcrop on south side of basin, at Hazleton Slope, No. 6,	+1672
Bottom of Mammoth bed basin,	+ 850
Width of basin along line through Slope No. 6, 3800 feet (.7 miles.)	

Western Middle Field, Mahanoy Basin.

Gilberton (P. and R. R. depot,)	+1183
Mammoth bed outcrop on north side of basin, at Gilberton slope,	+1223
Mammoth bed outcrop on south side of basin, at Draper slope,	+1275
Bottom of Mammoth bed basin, (estimated,)	— 150
Width of basin along line through Gilberton slope, 3050 feet (.6 miles.)	

* Depth attained by workings in Prospect colliery is now over 300 feet below ocean level.

Southern Field, Panther Creek Basin.

(Near Tamaqua.)

Tamaqua (P. and R. R. depot,)	+ 803
Mammoth bed outcrop on north side of basin,	+1250±
Mammoth bed outcrop on south side of basin,	+1300±
Bottom of Mammoth bed basin, (estimated,)	—1000
Width of basin, 5700 feet (1.1 miles.)	

The region is exceptionally free from rock faults. No downthrow or upthrow faults have been defined, such as are so frequently met with in the English coal-fields, where the *hade* of the fault makes an angle of more than 90 degrees with any one stratum on either side of the fault plane. The only breaks in the strata which are worthy of mention, in this brief description, are the fractures which occur along the reversed flexures, and which are properly called reversed faults. When the strata were corrugated and the overturns formed, the tension of the strata along the axis of the isoclinal was so great that those on the upper side of the axial plane were shoved past those on the lower side; * these faults seldom amount to more than 300 or 400 feet, and in most cases where coal-beds are enclosed in the faulted strata, the coal-beds have been continued along the fracture or fault plane, but generally in a dirty, unworkable condition. Such faults have been encountered in the vicinity of Shenandoah, and along the side of Bear Ridge, in Schuylkill county, and in the vicinity of Hazleton, Plymouth, and Wilkes Barre, in Luzerne county.

6. *Stratigraphical Geology.*

The rocks outcropping in the region are stratified, and were deposited during the Palæozoic Era.

The thicknesses of the several formations vary considerably along their outcrop in different portions of the field; their lithological characteristics are sufficiently constant, however, to permit of an easy recognition by the experienced geologist wherever they are exposed. The names of the periods and epochs under which these strata have been commonly grouped, with their accompanying thicknesses, as

* Faults of this character are illustrated, in the case of the Alps, by Heim, in his work on Mountain-making.

determined by the Geological Survey along the Lehigh river in Carbon county, south of the eastern end of the Southern field (Fig. 1,) are exhibited in the following table:

Palæozoic Era.

I. Carboniferous Period.

			Feet.
XIII.	Productive Coal Measures		975
XII.	Pottsville Conglomerate (Seral, Millstone Grit,)		880*
XI.	Mauch Chunk Red Shale (Umbral,)		2170
X.	Pocono Sandstone and Conglomerate (Vespertine,)		1255

II. Devonian Period.

IX.	Catskill Sandstone (Ponent,)		7145
VIII.	Chemung Shales and Sandstones, Portage Shales and Flags,	Vergent,	1290
	Genessee Slates and Shales,	Cadent,	290
	Hamilton Sandstones and Flags,	Cadent,	760
	Marcellus Shales and Slates,	Cadent,	800
	Upper Helderberg Limestone, Caudi Galli and Schoharie Grits,	Post Meridian.	Absent.
VII.	Oriskany Sandstone, (Meridian,)		340

III. Upper Silurian Period.

VI.	Lower Helderberg Limestones and Shales, (Pre-Meridian,) Onondaga Shales, (Scalent,)		295
V.	Clinton Red and Gray Shales, (Surgent,)		2000
IV.	Medina Sandstones, Oneida Sandstones and Conglomerates,	Levant,	460

IV. Lower Silurian Period.

III.	Hudson River Slates, Utica Slates,	Matinal,	6000±
II.	Trenton and Calciferous Limestones, (Auroral,)		2000±
I.	Potsdam Sandstone, (Primal,)		—

The numbers assigned to the epochs and formations are those which were adopted by the First Pennsylvania Survey. The geographical names were first proposed by the New York State Survey, and have been generally made use of by geologists, wherever the strata composing these formations could be identified, throughout the Appalachian region. The New York nomenclature, as originally pro-

*Only 240 feet thick on the Ashley planes, and not over 100′ at a number of places in the Wilkes Barre mountains.

posed, ended with the Catskill, and the names Pocono, Mauch Chunk, and Pottsville, were first suggested for the higher Pennsylvania rocks by Prof. Lesley, in 1875. The names placed in brackets were introduced by Prof. H. D. Rogers during the progress of the First Pennsylvania Survey. They have, however, never been generally adopted.

The areas in the region underlaid by the formations Nos. XII, XI, and X are generally easily defined by the topography which they produce, although in places no actual exposed outcrop may be found. The Pottsville Conglomerate forms a rim around the coal-basins, and the Pocono Sandstone and Conglomerate an outer rim, with a valley included betwen them eroded out of the Mauch Chunk Red Shale.

The thickness of the Pottsville Conglomerate varies greatly. In Nesquehoning gap it measures 1155 feet (Fig. 3.) Two miles to the east, midway between Nesquehoning gap and Mauch Chunk, it is about the same thickness, while four miles to the west, in the Nesquehoning Railroad tunnel,* it measures only 880 feet, as given in the table of formations. In Locust Mountain gap, directly north of Tamaqua, about five miles a little south of west of the Nesquehoning Railroad tunnel, it measures 1280 feet. This variability in the thickness of the Pottsville Conglomerate within short intervals, may show an unconformability between the underlying Mauch Chunk Red Shale, No. XI, (representative of the Sub-carboniferous or Mountain limestone,) or an unconformability between the individual strata forming the conglomerate measures. It is more probable, however, that this change in thickness is due to an unevenness in the bottom of the water basin at the time that deposition took place, or to variable and changing water currents.

The facts at present obtained do not seem to be sufficient to attempt a final solution of the question. Prof. Lesley,

*The Rhume Run tunnel, back of the village of Nesquehoning, is frequently called the Nesquehoning tunnel and was used solely for mining purposes; it must be distinguished from the Nesquehoning Railroad tunnel through the Locust mountain, north of Lansford.

in referring to this phenomenon, concludes that, "The variable thickness of the conglomerate must be discussed on one of two hypotheses: either, we must surmise extraordinary and unaccountable variations in the quantity of sand and gravel deposited on neighboring parts of the red shale sea bottom; or, we must apply the mechanical law, that the folding of a plastic mass shifts all parts of the mass to allow of its accommodation in a smaller space."

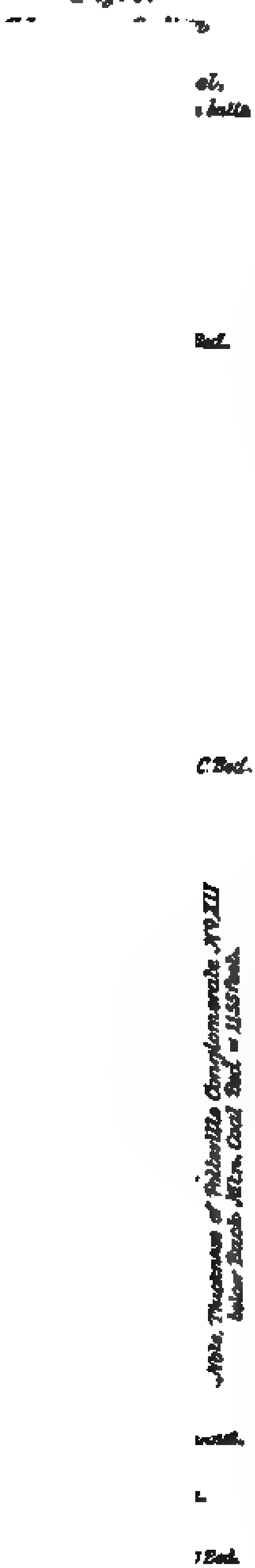
The thickness of No. XII declines rapidly towards Wilkes Barre. At the Red Ash colliery, which is 25 miles due north from the Nesquehoning R. R. tunnel, and immediately south of Wilkes Barre, the conglomerate measures but 96 feet. This change in the thickness of the conglomerate is as great in other directions, as shown by numerous sections made by the Geological Survey.

The variability in the thickness of the Productive Coal Measures, and of their included coal-beds, is relatively almost as great as that of the conglomerate; it would be impossible to select any one section to illustrate the thickness, character, and succession of the coal-beds and their included rocks throughout the region.

The non-parallelism of the anthracite beds, in many localities, is now proven beyond a question. In fact, it is doubtful whether the certain identification of any of the Carboniferous strata, over the entire coal-region, can be accepted as at present determined, other than that of the Mammoth coal-bed and the base of the Pottsville Conglomerate, No. XII. Until the relationship of the anthracite beds in the different districts is established, it is folly to attempt, as has often been done, to identify the anthracite coal measures with those in the Pennsylvania bituminous fields.

The accompanying section, (Fig. 3,) measured in the Nesquehoning or Rhume Run tunnel, is as representative of the anthracite measures as any which could probably be referred to. The Mammoth bed, which is 13 feet 10 inches thick in this section, changes, as do all the other coal-beds, very much in thickness, in the number of separate benches of coal which it contains, and the amount of

Fig. 3.



slate and poor coal which is included between the good coal benches or layers. Half a mile west of Summit Hill village, where the coal was first quarried in a surface cutting in 1792, the bed is about 50 feet thick. At one point, where a very careful measurement was made, the bed was composed of 21 separate benches of coal, having an aggregate thickness of 40 feet 3 inches, which were separated by 20 layers of slate, with a total thickness of 12 feet 10 inches. The average thickness of the bed east of the Nesquehoning colliery is estimated to be 29 feet, with 23 feet of merchantable coal, and west of Rhume run to the Schuylkill-Carbon county line, 55 feet, with only 27 feet of coal.

Between the county line and Tamaqua the average thickness of merchantable coal contained in the Mammoth bed is about 27 feet, and the average thickness of the coal-bed itself is 43 feet. In colliery No. 9 of the Lehigh Coal and Navigation Company, west of Summit Hill village, the Mammoth bed has an average thickness of 50 feet, and contains on the average 25 feet of merchantable coal. At one point in the colliery, where the bed and accompanying strata have evidently been subjected to a local lateral compression, the coal-bed measures 114 feet thick, and contains 106 feet of coal; while a thickness of 60 or 70 feet for the bed, with 40 or 50 feet of good coal contained in it, is not unusual at many points in this mine.

The Red Ash bed, which is the bed most extensively worked in the Panther

Creek valley, next to the Mammoth, has an average thickness in the eastern and western ends of the basin of about 13 feet, containing 9 feet of coal, while in about one third of the area of the basin, near its center, the same bed has an average thickness of 9 feet, with only 5 feet of coal.

In the Greenwood colliery workings, near Tamaqua, the following measurements were made:

Bed.	Average dip.	Coal-bed.	Coal.	Per cent. of coal taken out of mines.
G.	57°	3 feet.	2 feet.	60
F.	57°	12 "	10 "	50
E.	51°	20 "	15 "	70
D.	57°	9 "	7 "	60
C.	57°	8 "	6 "	60
B.	57°	6 "	3 "	50
A.	55°	10 "	8 "	70

These facts, although local, are sufficient to show the great variability of the anthracite coal-beds and the impossibility of reporting a section of any one bed which shall be an average for any considerable portion of the region. In the First Report of Progress of the Anthracite Survey a number of sections are given, with a view of indicating, as near as possible, the average thickness of the Coal Measures, and the average thickness of the coal-beds contained in a number of localities. A summary of these sections is given in the following table:

Location of Sections.	Total thickness of coal measures.	Total thickness of coal-beds.
Northern Field.		
Carbondale Basin, Forest City colliery, ...	307′ 7″	19′ 6″
" " near Carbondale, ...	282′ 2″	13′
Lackawanna Basin, near Scranton, ...	633′	67′
Wilkes Barre Basin, near Wilkes Barre, . . .	867′ 3″	85′ 3″
Nanticoke Basin, near Nanticoke, ...	918	95′ 6″
Eastern Middle Field.		
Black Creek Basin, near Gowen, ...	558′ 1″	38′ 1″
" " " near Ebervale, ...	369′	36
Hazleton Basin, Hazleton colliery, ...	528′ 1″	81′ 4″
Western Middle Field.		
Mahanoy Basin, Ellangowan colliery, ...	767′	107′ 9″
Shamokin Basin, Trevorton Estate, ...	1408′	117′
Southern Field.		
Panther Creek Basin, near Tamaqua, ...	2168′	126′
Pottsville Basin, near Pottsville, ...	3097′	154′

The thicknesses assigned to the coal-beds does not represent the thicknesses of merchantable coal contained in the beds, but the thickness of the beds, including the layers of slate and bony coal contained between the benches of good coal.

On the accompanying sheet of columnar sections of the Anthracite Coal Measures, showing the relationship of the coal-beds in areas, mapped by the Geological Survey prior to January, 1886, are contained 15 sections, which exhibit the number and average thickness of the coal-beds, and the thickness of the rocks between the coals, for each of the 15 mine sheets which have so far been published. Six of these mine sheets relate to that portion of the Northern Coal-field in the Wyoming Valley, between Wilkes Barre and Nanticoke; two relate to that portion of the Eastern Middle Coal-field, (Lehigh Coal-field,) in the region surrounding Drifton and Hazleton; four of them embrace the eastern end of the Western Middle (Mahanoy-Shamokin) Coal-field, between Delano and Ashland; and three relate to the extreme eastern end of the Southern Coal-field, between Mauch Chunk and Tamaqua, which latter area is locally known as the Panther Creek Coal-basin, and is referred to generally by the coal trade as the Lower Lehigh region.

NAME OF MINE SHEETS AND LOCATION OF SECTIONS.	Total thickness of coal measures.	Total thickness of coal measures above Buck Mountain coal-bed.	Total thickness of coal-beds.
NORTHERN COAL-FIELD.			
Wilkes Barre, (Conyngham shaft and Baltimore and Red Ash bore-holes,)*	1060′	953′	95′
Kingston, (Kingston shaft, No. 3,)	534′	534′	57′
Ashley, (Stanton shaft and Empire tunnel,)	1047′	1047′	90′
Plymouth, (Plymouth shaft, No. 2, and bore-hole,)	860′	851′	106′
Warrior Run, (Hanover bore-hole,)	707′	576′	46′
Nanticoke, (Susquehanna shafts, Nos. 1 and 2,)	1010′	1010′	93′

* In these sections is included the Pottsville Conglomerate No. XII.

Name of Mine Sheets and Location of Sections.	Total thickness of coal measures.	Total thickness of coal measures above Buck Mountain coal-bed.	Total thickness of coal-beds.
Eastern Middle Coal-field.			
Drifton, (Drifton bore-hole, No. 8, and Lattimer bore-hole, No. 2,)*	761' 4"	515' 8"	71' 11"
Hazleton, (Hazleton slopes, Nos. 1 and 6, and bore-hole No. 19,)*	886' 1"	624' 2"	58' 3"
Southern Coal-field.			
Mauch Chunk, (Rhume Run tunnel and Nesquehoning gap,)*	1632'	807'	65'
Lansford, (Lansford basin and railroad tunnel,)*	1959' 8"	1444'	87' 3"
Tamaqua, (Locust Mountain gap,)*	3479'	2294'	126'
Western Middle Coal-field.			
Delano, (East Mahanoy tunnel and Primrose colliery,)*	1348'	489'	55'
Shenandoah, (Ellangowan and Indian Ridge collieries,)*	1193'	898'	118'
Girardville, (Hammond, Preston, and Girard Mammoth collieries,)*	1512'	969'	83'
Ashland, (Bell's tunnel and Potts' colliery,)*	1647'	1183'	106'

Although a comparative study of these 15 sections will not show all the changes in the thicknesses of the rock intervals and coal-beds in those portions of the anthracite region to which they relate, or will give even a general idea as to the succession of the strata and their individual thicknesses in other areas in the coal-region, yet they are sufficient to show the general character of the coal-basins, as far as the investigations of the Geological Survey have been carried, and in a measure they indicate the difficulties which must always beset any attempt, to establish the relationship of the coal measure sections and the identity of coal-beds over extended areas.

The thicknesses assigned to the Coal Measures above the Buck Mountain coal-bed may be taken to represent fairly

* In these sections is included the Pottsville Conglomerate No. XII.

the thicknesses of the productive strata above the Pottsville Conglomerate. I do not consider it a settled question that the Buck Mountain coal-bed marks the geological division between the base of the Anthracite Productive Coal Measures and the top of the Pottsville Conglomerate, nor is it so placed on all of the sheets of the Anthracite Survey; it is provisionally considered such, however, on some of the published sheets, and in this place, as a matter of convenience, to permit of a systematic comparison of the sections referred to in the respective areas. In sections Nos. 1, 7, 8, 9, 10, 11, and 12, the thicknesses of the Pottsville Conglomerate have been measured. They are as follows:

No. of Section.	Locality.	Thickness of No. XII.
1, ...	Wilkes Barre, ...	96′
7, ...	Lattimer, ...	244′
8, ...	Hazleton, ...	262′
9, ...	Nesquehoning, . . .	825′
10, ...	Lansford, ...	515′
11, ...	Tamaqua, ...	1191′
12, ...	East Mahanoy tunnel,	844′

From these figures it is seen that the conglomerate is thickest immediately north of Tamaqua, and thinnest immediately south of Wilkes Barre, being 1191 feet thick at the former locality, and 96 feet thick at the latter.

These facts would seem to indicate that the eastern end of the Southern Coal-field was nearer the source from whence the sediment forming the Pottsville Conglomerate was derived. The facts, however, are not sufficiently extended to permit of a satisfactory explanation of the dynamical conditions existing at the geological time during which the conglomerate and the more recent rocks of the Carboniferous Period were deposited. In a general way it might be reasonably inferred that the conglomerate thickened progressively between any two sections in this group. Such, however, is not the case, as shown by the following facts: At Hacklebarney tunnel, near the end of Sharp mountain, back of Mauch Chunk, the strata from the base of the Mammoth coal-bed to the top of the Mauch Chunk Red

CONVENTIONAL CHARACTERS
adopted for the
Columnar Section Sheets
of the
Survey of the Anthracite Coal Fields.

1	*Cribbing*	15	*Conglomerate*
2	*Masonry*	16	*Shale*
3	*Surface, Earth or Soil*	17	*Bone*
4	*Drift*	18	*Concealed Strata*
5	*Gravel*	19	*Dirt and Slate*
6	*Quicksand*	20	*Slate hard with iron balls*
7	*Clay*	21	COAL BED
8	*Clay and Sandstone*	22	*Fireclay*
9	*Slate*	23	*Fireclay and Slate*
10	*Slate and slaty Sandstone*	24	*Fireclay and Sandstone*
11	*Slate and Sandstone*	25	*Fireclay and Quicksand*
12	*Shaly Sandstone*	26	*Limestone*
13	*Sandstone*	27	*Shaly Limestone and Calcareous Shale*
14	*Conglomerate and Sandstone*	28	*Mauch Chunk Red Shale No. XI*

Strata not named in this list can be represented by a combinat. of the different characters indicated.

Lane S. Hart, State Printer.

Shale, No. XI, measures 1511 feet. These strata gradually thin toward the south-west to 900 feet at the Lansford Railroad tunnel, six miles distant. The thinning of the strata, however, between Hacklebarney and Nesquehoning being more gradual than the thinning between Nesquehoning and the Railroad tunnel, the minimum thickness of these strata in the Panther Creek basin seems to exist at the latter point; but they gradually thicken toward the south-west until in the Locust Mountain gap, eleven miles from the Railroad tunnel they measure 1700 feet in thickness.

This great thickening and thinning of this group of strata, in comparatively short distances, between points which were probably nearly equi-distant, from the source of the sediment composing the rocks, is most probably accounted for by the existence of local currents, at the time the deposition took place.

From a study of the latter facts at the time of their discovery in 1880, I was disposed to believe, as has already been suggested in this report, that the thickening of the Carboniferous strata from the Lansford Railroad tunnel east toward Mauch Chunk, and west toward Tamaqua, might indicate a non-conformability between the conglomerate and the underlying Mauch Chunk Red Shale, No. XI, or a non-conformability between the individual strata forming the conglomerate measures. Subsequent investigation has led me to conclude, however, that it will be impossible, at the present time, to offer a final explanation of this phenomenon until additional facts have been obtained.

The most marked differences in the thicknesses of the Coal Measures above the top of the Conglomerate have been found to exist in that part of the series between the Mammoth and the Buck Mountain coal-beds, both of which beds have been identified in the areas to which these sections relate. These differences are shown in the following table:

No. of Section.	Locality.	Thickness of the strata between the Mammoth and Buck Mountain coal-beds.
1, ...	Wilkes Barre, ...	309'
2, ...	Kingston, ...	265'
3, ...	Ashley, ...	393'
4, ...	Plymouth, ...	257'
6, ...	Nanticoke, ...	476'
7, ...	Drifton, ...	273'
8, ...	Hazleton, ...	208'
9, ...	Nesquehoning, ...	431'
10, ...	Lansford, ...	437'
11, ...	Tamaqua, ...	500'
12, ...	East of Mahanoy City, .	213'
13, ...	West of Mahanoy City, .	156'
14, ...	Girardville, ...	260'
15, ...	Ashland, ...	226'

The greatest variability in these sections is shown between Locust Mountain gap north of Tamaqua and the East Mahanoy Railroad tunnel, the latter point being about 7 miles north-west of the former.

The identity suggested for the two prominent coal-beds immediately above the Mammoth bed, in sections Nos. 8 to 15 inclusive, can only be considered provisional, although the facts at present at command would seem to warrant the conclusions deduced.

In order to make all the columnar sections of the anthracite region easily comparable, in a graphical way, both on the atlas sheets and in the report where these sections have been drawn in a vertical column, it became necessary to adopt a uniform system of shading, to represent the different character of strata. After a careful comparison of all the conventional signs used for such shading by different government surveys, by private mining engineers, and by expert draughtsmen, I finally proposed the system represented on the accompanying page plate No. II. This system is now universally used by the Geological Survey in shading all Coal Measure columnar sections.

7. *Mining.*

The general methods of opening the anthracite mines are various, depending largely upon the mode of occurrence of

the coal-bed. The early mines were mostly excavated out of the coal-beds above water-level, in order to obtain natural drainage. This was accomplished, (1) by quarrying the coal at a natural outcrop, as at the old Summit Hill mines, and as is being done at present in the vicinity of Hazleton; (2) by water-level drifts, driven along the strike of the bed; (3) by water-level tunnels driven across the coal-beds perpendicular to the strike [the drift and tunnel plans are illustrated by many of the abandoned mines, and those which are still being worked in Schuylkill and south-western Carbon counties;] (4) by slopes driven down the dip of the bed; and (5) by vertical shafts.

Between the lowest point of outlet to the mine and the outcrop of the coal-bed, the coal is worked from nearly horizontal gangways driven along the strike of the bed; the coal between any two gangways being worked out from the lower one, by the ordinary pillar and breast system. In high dipping beds the lift, or distance along the dip of the bed between any two gangways, varies from 75 to 100 yards. In beds with low dips the positions of the gangways are dependent upon local conditions. The size of the gangways, pillars, and breasts or chambers varies according to circumstances.

There are many modifications in the details of the pillar and breast system, that most generally employed in the region, which are to some extent dependent upon the choice of the mine superintendent, but more generally are governed by the lay of the coal-bed, its thickness, and the constitution and character of the enclosing rocks.

The percentage of the amount of coal which is originally contained in the ground before mining is commenced, which is left in as pillars for roof support, and the percentage which is taken out, is variable. In the high dipping beds of the Panther Creek basin, between Tamaqua and Mauch Chunk, the percentage of coal which has been taken out of the individual mines, from their original opening to the present time, varies between 51 and 65 per cent.; while for the entire basin, between the years 1820 and 1883, the amount of coal removed was 59 per cent., and that left in the pillars

and other portions of the mines was 41 per cent. of the original contents.

The better and more economical methods of mining which have been introduced into this basin during the past few years have resulted in taking out of the mines, for the years 1881 and 1882, 70 per cent. of the original coal contained. In other portions of the region, notably in limited sections of the Northern Coal-field, where the beds do not dip as steeply as in the Southern field, and where the conditions for more economical mining generally obtain, as much as 80 or even 85 per cent. of the coal originally contained is said to be taken out of the mines.

This percentage does not represent the amount which is converted into commercial fuel, since the coal has to be broken into market sizes and has to be freed from the slate and bad coal which is mixed with the good coal when sent from the mine to the breaker. This preparation of coal for market is attended with great waste. In the Panther Creek region, between the years 1820 and 1883, 32 per cent. of the coal originally contained in the worked areas was sent directly from the mines and breakers to the dirt banks as waste, and only 27 per cent. was converted into fuel coal. During the years 1881 and 1882 the waste coal only amounted to 24 per cent. of the original contents, and as much as 46 per cent was converted into fuel coal. This shows that from 1820 to 1883 of the 59 per cent. of the original contents of the coal-beds which was taken out of the mines, more than half (56 per cent.) was thrown on the waste heap, while a little less than half was converted into fuel. During the years 1881 and 1882, of the 70 per cent. of the original contents taken out of the mines, only one third (34 per cent.) was thrown on the waste heap, and two thirds were converted into fuel. This gain is due to two causes: First, to mechanical improvements and greater economy in breaking the coal; and, second, to the present consumption of the smaller sizes of coal which were formerly thrown away on the dirt bank.

The waste in the preparation of coal is due to breaking, to screening, and to attrition while the coal is passing from

the shutes to the pockets and market cars. This waste is dependent upon so many varying conditions connected not only with the construction and working of the breaker, but upon the character of individual coals, that it is impossible to give an average for the region. In the Shenandoah district the waste in breaking and preparing the Mammoth coal at a number of collieries was found to be 15 per cent. In the vicinity of Wilkes Barre, in preparing coal from the Red Ash bed at several collieries, but 6 per cent. of waste was obtained, while in preparing coal from the Baltimore or Mammoth bed about 11 per cent. of waste resulted. In the Shamokin district the waste from breaking and screening is reported in some cases to be as high as 25 and 30 per cent.

The utilization of the waste coal, which is now thrown on the dirt or culm bank, is a question of great economical importance to this region. Several methods have been suggested for preparing the fine coal and manufacturing it into blocks of various sizes, none of which have yet come into general use. While it would seem to be practical to manufacture such fuel under particularly favorable conditions, I believe that the final solution of the problem is not the manufacture of the waste coal into forms which would make it a possible fuel, with the same conditions of combustion under which the various sizes of broken anthracite are used, but rather to manufacture a special form of grate and furnace where the waste coal can be consumed in its present form. Of course, where the culm is filled with poor coal and slate, this must be removed in order to obtain the best results. In other words, the design of the furnaces must be adapted to the existing form of the coal, and not the form of the coal adapted to the existing forms of furnaces. I believe the most practical results in making use of waste coal have been obtained by Mr. J. E. Wootten, General Manager of the Philadelphia and Reading Railroad, who has designed a special form of grate and furnace for its consumption in its natural condition.

CHAPTER II.

The Classification and Composition of Pennsylvania Anthracites.

1. Classification.

The manufacturing and domestic consumers of anthracite are beginning to realize the fact more fully, that the coal purchased for any one year does not seem to burn so freely, does not fire with so little trouble, and does not last so long as that purchased during other years, or *vice versa*. Where coals of different sizes, or from different districts, are offered to the trade by the same or competing salesmen, the question suggests itself, which shall we buy?

Among housekeepers, who are the most numerous class of consumers, though on the smallest scale, distinction is seldom recognized among these anthracites. By other consumers the coals are grouped into those which, when burned, will produce either a white or red ash, special qualities being arbitrarily attached to each. Others, again, know only of three varieties: (1) Those from the Wyoming and Lackawanna fields, or the coals shipped from the northernmost basins over the railroads running through north-eastern Pennsylvania direct to New York—notably, the Delaware, Lackawanna and Western, Delaware and Hudson, and Erie Railways; (2) those shipped by the Lehigh Valley Railroad and the Lehigh and Susquehanna division of the Philadelphia and Reading Railroad down the Lehigh Valley; and (3) those shipped over the main line of the Philadelphia and Reading Railroad down the Schuylkill Valley. In special localities, where a favorite coal is largely used, the consumer will speak of one class, composed of his favorite coal, which possibly comes from two or three collieries, with a total aggregate annual production of less than a million tons; and of a second class, composed of the coals from all

the other collieries in the anthracite region, represented by an annual production of over thirty million tons. This can be noticed particularly in sections of New England, where even an intelligent consumer will sometimes speak of Lykens Valley coal as one kind, and of all other Pennsylvania anthracites as the other kind.

One of the most extensively discussed questions connected with the Pennsylvania anthracite and bituminous regions, and one about which the most unsatisfactory conclusions have been arrived at, has been the classification of the coals. The original division of our Pennsylvania coals into anthracite, semi-anthracite, semi-bituminous, and bituminous, was one founded largely upon their geographical distribution, although the supposed basis was the chemical composition of the coals. These names, as they have been indelibly fixed upon coals produced from special sections or individual mines, will always, to some extent, be made use of by the coal trade; they have, however, no scientific value. An interesting discussion of this subject was contributed to the *Transactions** of the Institute, by Dr. Persifor Frazer, and was subsequently published in *Report MM of the Second Geological Survey of Pennsylvania.* As a result, the following classification † is suggested:

Classes of coals.	Ratio $\frac{\text{C.}}{\text{Vol. H. C.}}$: 1.
Hard-dry anthracite, ...	from 99:1 to 12:1
Semi-anthracite, ...	from 12:1 to 8:1
Semi-bituminous, ...	from 8:1 to 5:1
Bituminous, ...	from 5:1 to 0:1

In arranging the coals under this classification, and many others proposed, the accidental impurities, such as sulphur and earthy matter, are disregarded in the analysis, and the fuel constituents are alone considered. The carbon-ratio‡ of

* Volume VI, page 434.

† See Report AC, page 15.

‡ This ratio has always been referred to as the "*fuel-ratio.*" While this naming is commonly used I have found that it conveys a wrong impression to practical men, since they are disposed to consider a coal with a relatively high fuel-ratio a better fuel than a coal with a relatively low fuel-ratio. Such is not the case, since the actual power of a coal to produce heat units is more dependent upon the percentage of accidental impurities which it contains, than upon

each coal, or the fixed carbon divided by the volatile hydrocarbon, is represented by the first term of the ratio expressed in the table on page 14. While this classification is probably the best which has been suggested for our Pennsylvania coals, and may be used provisionally as a scientific basis, the coals as at present graded by the coal trade could not be arranged under this or any other chemical classification; and I do not believe that we have sufficient data now at command to suggest a final arrangement which might be considered a scientific rating of the coals, and which would be accepted by the coal miners, venders, and consumers.

The producers and sales agents classify the coal from individual collieries and from a group of collieries under special heads. The individual characteristics which are assigned to each separate coal, are supposed to be dependent upon the appearance of the coal, its hardness, the ease with which it burns, and the color of its ash, or the locality from which it is obtained. In the latter case the geographical name is indicative of the recognized character.

Mr. John H. Jones, accountant of the anthracite transportation companies, in his list of collieries which he has been in the habit of publishing annually until the past year, has noted, in addition to other valuable information, the character, as reported to him, of the coal shipped from each colliery. The kind of coal obtained from each colliery has been often arbitrarily assumed by the trade,* and the

the ratio which exists between the fixed carbon and the volatile hydro-carbon; if this was not so a bituminous coal with a fuel-ratio of 1, that is a coal containing equal proportions of fixed carbon and volatile hydro-carbon, might be considered to be worthless as a heat producer, and a hard-dry anthracite with a fuel-ratio of 99, that is, a coal containing 99 times more fixed carbon than volatile hydro-carbon might be considered the highest type of a heat producer, although the bituminous coal might contain only 4 per cent. of ash and the anthracite 12 per cent. In order to prevent such erroneous comparison of coals I propose to substitute the name "*carbon-ratio*" for "*fuel-ratio.*"

*A prominent anthracite operator related to me an incident which illustrates the prejudices of the trade in regard to the values of coals. This gentleman was operating a colliery between Shenandoah and Mt. Carmel, which was connected with both the P. & R. R. R., which transported their coal down the Schuylkill Valley, and the L. V. R. R., which shipped their coal to market down the Lehigh river. A contract was made for regular shipments of coal from this colliery over the L. V. R. R. at a time when there was a discrim-

fact that two collieries in the same district have been reported as producing the same kind of coal, has been no certain criterion of the true worth of either coal to the consumer.

In some cases the names which have been given different coals have been unquestionably adopted on account of the favor which they would thereby secure with the trade and consumers. It has been found by experience that coal coming for several months from certain parts of the mines, at an individual colliery, may reasonably be called a red-ash; and, in a number of months immediately following, when the coal is brought from a different part of the mines, it would more fairly be called a white-ash. The name by which such a coal is known, however, may not be changed on account of an absolute difference in the character of the coal, but when the fact is once established that a change in name will warrant a more favorable reception by a certain class of consumers, and that the sales of the colliery can thereby be increased, it will quickly insure a new classification.

The coals of the producing collieries during the year 1884 have been classified under the general heads* in the following table, which, in addition, shows the number of collier-

ination of 50 cents between the Lehigh and Schuylkill coals in favor of the Lehigh, the coal trade generally understanding that Lehigh coal was coal shipped over the L. V. R. R., and Schuylkill coal that shipped over the P. & R. R. R.

The L. V. lateral which took his coal to the main line of the road was temporarily closed, and he was compelled in consequence to fill his orders by shipment over the P. & R. R. R. But a few days elapsed before his consignee complained of receiving a very inferior Schuylkill coal instead of the superior Lehigh coal which he had formerly received, and the operator was forced to make a rebate of 50 cents a ton on the coal which he had temporarily shipped over the P. & R. R. R.

It is gratifying to know that among the more *intelligent consumers* no difference is now recognized between certain coals transported through the Lehigh Valley and others through the Schuylkill Valley. In fact several favorite brands of coal, which cannot be excelled, are now shipped almost entirely down the Schuylkill Valley. (See First Rep. Anth. Reg., p. xxxi.)

*This grouping of the coals into ten classes is, without doubt, the best and fairest which has ever been proposed by the coal trade, and is now extensively made use of. In many of the market reports the coals are divided into but two classes, the free-burning and hard white ash coals. In this connection the

ies producing each kind of coal, and in the amount in tons, and percentage of each :

Character of coal.	Number of collieries.	Production 1884. Tons.	Percentage of total production 1884.
1. Free-burning White Ash,	218	17,109,523	52.41
2. Hard White Ash, . . .	105	9,206,639	28.20
3. Wyoming Red Ash, . .	14	1,727,965	5.30
4. Lehigh Red Ash, . . .	11	1,510,494	4.63
5. Shamokin,	29	1,409,854	4.32
6. Lykens Valley Red Ash,	8	1,145,008	3.50
7. Schuylkill Red Ash, . .	14	227,467	.71
8. Trevorton, ...	2	116,695	.36
9. Lorberry Red Ash, . .	4	101,836	.31
10. Bernice White Ash, . .	1	86,018	.26
Total, ...	401	32,641,499	100.00

Mr. Joseph S. Harris, in speaking of the characteristics of the coals produced from the properties of the Philadelphia and Reading Coal and Iron Company in the Western and Southern fields, defines the characteristics of many of these different varieties. Although his definitions were not intended to include the coals from the Eastern, Middle, and Northern fields, yet, in a general way, they may be considered equally applicable to the special coals from these latter fields. His definitions are as follows:

(1.) *Hard White-Ash.*—"It is in great request for blast-furnace and locomotive purposes, having, to an unusual degree, the qualities of resisting change of form under high heat and pressure, and, owing to its high percentage of carbon, it is valuable for producing steam; but for domestic use on a small scale, and for open-grate fires, it does not ignite readily enough to be a favorite."

(2.) *Free-burning White-Ash.*—"The distinction between it and the hard-

---

following prices showing the fluctuations of anthracites f. o. b., in New York Harbor during 1885, may be of interest:

Free-burning.

	Lump.	Grate.	Egg.	Stove.	Chestnut.
Lowest, ...	$3.30	$3.00	$3.00	$3.50	$3.10
Highest, ...	3.45	3.25	3.40	4.10	3.60

Hard White Ash.

	Lump.	Grate.	Egg.	Stove.	Chestnut.
Lowest, ...	$4.25	$3.35	$3:25	$4.00	$3.40
Highest, ...	4.75	3.50	3.40	4.25	3.75

burning white-ash coal is, that under such a fire as is ordinarily used for smelting metals or producing steam, the impurities melt or clinker, which is not the case with the harder coal. This practical test is not, however, a very exact one. Some of the anthracites can be clinkered with a strong draft and with a thick bed of fire, and would, by a person who used them under such circumstances, be classed as free-burning, while another, whose method of burning was more economical, would call them hard. Analysis shows that the free-burning white-ash coals are quite as rich in fixed carbon, and that they have even higher heating power, as tested by the amount of water evaporated, than the harder variety, but their limited range of usefulness, which is due to their clinkering, prevents their price rising as high as the hard white-ash coals."

(3.) *Schuylkill Red-Ash.*—"It is easily ignited, easy to keep burning, and where used in open grates makes less floating dust than white-ash coal, because its ash is composed of larger particles, and on account of the oxide of iron, which constitutes its coloring matter, has greater specific gravity than the ash of the white."

(4.) *Shamokin.*—"It follows in hardness, and in ease of ignition, next after the free-burning white-ash coals, and is used still more especially for domestic purposes, its lower percentage of carbon making it ill-adapted for purposes requiring intense heat."

(5.) *Lorberry Red-Ash.*—"It burns with a little flame, and is much in request for domestic uses in the Eastern market."

(6.) *Lykens Valley Red-Ash.*—"It burns with considerable flame, and is greatly liked in the Eastern market for open grates, other domestic uses, and for steam and heating purposes, wherever quick heat is required."

(7.) *Trevorton or North Franklin White-Ash.*—The coal is pure, but its heating properties are rather low, and it is of so friable a nature that it does not stand transportation well."

The (8) Wyoming red-ash, (9) Lehigh red-ash, and (10) Loyalsock white-ash are not referred to in Mr. Harris' report. The Wyoming red-ash is similar in its general characteristics to the Schuylkill red-ash. The Lehigh red-ash is very similar to the hard white-ash produced from the same region, with the exception of the color of the ash, due to the presence of iron, the same as in the softer red-ash from Schuylkill, while the Bernice white-ash, as a fuel, is rated by many coal men as being similar to the Lykens Valley coal, except in the color of the ash. The geological structure and physical characteristics of the Bernice and Lykens Valley beds are, however, quite different.

The following table shows the amount of the different kinds of coal produced in the different fields, the number of producing collieries in each field from which the different varieties of coals come, and the proportion produced, both in tons and per cent of production:

Coal Field.	Character of Coal.	Number of collieries.	Production. 1884. Tons.	Percentage of total production, 1884.
Northern, . . .	Free-burning White-Ash, .	155	14,683,312	44.98
	Wyoming Red-Ash, . . .	14	1,727,965	5.30
	Total, ...	169	16,411,277	50.28
Eastern Middle,	Hard White-Ash, ...	44	3,588,190	10.99
	Lehigh Red-Ash, ...	11	1,510,494	4.63
	Total, ...	55	5,098,684	15.62
Western Middle,	Hard White-Ash, ...	46	4,572,762	14.01
	Free-burning White-Ash, .	20	1,796,738	5.50
	Shamokin, ...	29	1,409,854	4.32
	Trevorton, ...	2	116,695	.36
	Total, ...	97	7,896,049	24.19
Southern, ...	Lykens Valley Red-Ash, .	8	1,145,008	3.50
	Hard White-Ash, ...	15	1,045,687	3.20
	Free-burning White-Ash, .	38	629,473	1.93
	Schuylkill Red-Ash, . . .	14	227,467	.71
	Lorberry Red-Ash, ...	4	101,836	.31
	Total, ...	79	3,149,471	9.65
Western Northern	Lykens Valley White-Ash,	1	86,018	0.26
Grand total,	. . . .	401	32,641,499	100.00

It is not possible from this grouping of the coals to infer that all of the hard-ash coals are of equal value to consumers,* since the value of an individual coal as fuel is sometimes more dependent upon the care with which it is

*In this connection a paper recently read before the American Institute of Mining Engineers, by Dr. H. M. Chance on "The Relative Value of Coals to the Consumer," illustrated by a comparison of the coals mined from the Freeport Lower and Kittanning Lower bituminous beds of north-western Pennsylvania, is of special value.

prepared, than of the way in which the pure coal ignites, burns, or the color of the ash which it produces. The grouping of the coals in this way, however, is of interest and value as an indication of the general varieties and the amount of each produced.

2. Composition Pennsylvania Anthracites.

The pressing demand which has been made on the Geological Survey of Pennsylvania for some information as to the fuel-value of different coals, has led to a consideration of what is the composition of Pennsylvania anthracite, as a preliminary step in the investigation.

In ascertaining the fuel-value of a coal the primary consideration is an estimation of its calorific power, which is generally stated in units of weight of water converted into steam by the combustion of one unit of weight of coal. Analyses showing the percentage of the common constituents of coal, which may be generally classed under the heads of water, volatile matter, fixed carbon, and sulphur, and the amount of coke produced, are all important elements in the practical valuation of a fuel. A study of the characteristics of the coal, directly connected with its physical structure, and a determination of the amount of slate and slaty coal which exists in the market product, resulting from poor mining and imperfect preparation, but which might be economically removed by mechanical separation, are, also, questions of great importance to the consumer.

Professor Charles E. Munroe, in an important paper on "The Valuation of Coal," * says: "The heat developed by a fuel depends upon the union of the carbon, hydrogen, and other combustible constituents which it contains, with the oxygen of the air, and since, also, the heat produced by the combustion of measured quantities of each of these substances in oxygen has been determined with great accuracy, it would appear a simple thing to determine the calorific power of a coal by subjecting it to an elementary analysis, and calculating from the weights of the elementary

---

**Proc. U. S. N. Inst.*, vol. vi, No. xiii, page 222.

substances obtained the heat produced by its combustion; and this method has been followed, to a considerable extent, in the past, but it has been found in practice to give very erroneous results."

This conclusion is amply borne out by the results of the investigation of many practical chemists and physicists. The tests of Scheurer-Kestner and C. Meunier,* of European and English coals, show that in calculating the calorific power by the ordinary rule, from analyses of coal specimens, and determining the heat of combustion by direct experiment, the results varied at times as much as 15 per cent.; those based on chemical analyses always being lower than those determined by practical experiment.

The governmental researches made by Professor Johnson in 1842, and those made by Quartermaster-General M. C. Meigs, and reported to the Secretary of War in January, 1882, prove wide differences in the fuel-value of many of the Pennsylvania anthracites, and clearly indicate the economy in the purchase of special coals, although at the present time the coal trade makes no reliable distinction between coals which by tests of samples have been shown to have different evaporative capacities.

Mr. William Kent, a member of the Institute, who has given the fuel question much attention, admits that chemical analyses and especially ultimate analyses for total carbon, hydrogen, oxygen, and nitrogen are valuable guides in estimating the calorific power of coal, when properly burned, although he claims that the results of the tests of Johnson and Meigs indicate a directly opposite conclusion.

The experiments† of Professor William Foster on the composition and destructive distillation of coal, with special reference to the sulphur and nitrogen contained in six specimens of coal, representing the best known types found in many parts of the United Kingdom, and taken from widely separated localities, with the view of making the results as representative as possible, together with a discussion of the

---

**Ann. phys. et chim.*, 4 ser., t. xxi, et xxvi.

†*Proc. Inst., C. E.*, vol. lxxvii, part iii.

paper by Mr. I. Lowthian Bell, and Sir Frederick Bramwell and others, are of the greatest value.

A review of the work of the above and other investigators proves the practical necessity of there being made new and extensive tests as to the proximate composition and fuel-value of American coals.

Such tests the author proposed in 1883,* should be made by the Second Geological Survey of Pennsylvania, but it is doubtful whether any State could afford to make the investigation sufficiently extended to be of the greatest value.

Prof. E. P. Dewey, Curator of Metallurgy, National Museum, within the past year has suggested an admirable plan for making practical tests of American coals, and it is hoped Congress may make necessary appropriations for carrying this work on.

In the absence of more elaborate tests, a statement of the composition of Pennsylvania anthracite, as recently determined by Mr. A. S. McCreath, for the Geological Survey; and by Dr. Charles M. Cresson, for the Philadelphia and Reading Railroad Company, will no doubt prove of interest and value.

Various percentages of fixed carbon have been assigned by different authorities to a typical anthracite. That which has been most generally accepted has been about 94, with all the accidental impurities, such as those which are generally classified under ash and sulphur, eliminated. Professor Rogers (final report of the First Survey, Vol. II, pp. 969, 970,) gives analyses of fifteen specimens of hard dry Pennsylvania anthracites, which show an average: of fixed carbon, 88.05; of volatile matter, 5.81; of ash, 6.14. Eliminating the ash from these analyses, the percentage of the constituents of fuel are as follows: fixed carbon, 93.8; and volatile matter, 6.2.

The range of fixed carbon in the analyses of these fifteen specimens was from 94 to 80; the specimen showing the maximum being obtained from near Pottsville, and that showing the minimum from near Pine Grove, both from the

---

**First Report of Progress in the Anthracite Coal Region*, page xxxi.

Southern field in Schuylkill county. The range in volatile matter in the fifteen analyses is from 1.40 to 9.53; the minimum amount being in the same Pottsville specimen, and the maximum in a specimen from Black Spring Gap. The range in ash was from 2.90 in a specimen from Tamaqua, to 12.28 in the Pine Grove specimen. These results are certainly misleading, for it has been a long-recognized fact, that the coals obtained in the Southern field do not contain the highest percentages of fixed carbon.

Taylor (*Statistics of Coal*, 2d ed., p. 609,) gives analyses of a number of Pennsylvania anthracites reported from various sources. Twelve specimens from the Panther Creek basin, between Mauch Chunk and Tamaqua, show the following:

	Average.	Maximum.	Minimum.
Carbon,	89.21	92.60	86.00
Volatile matter,	6.38	8.00	4.45
Ash,	4.41	7.00	1.28

Six specimens from the Lehigh region gave:

	Average.	Maximum.	Minimum.
Fixed carbon,	89.00	92.30	85.34
Volatile matter,	7.05	9.60	5.36
Ash,	3.93	8.73	1.28

All of these analyses, particularly those given by Taylor, are constantly quoted in numerous descriptions of Pennsylvania anthracite found in technical publications, both at home and abroad. The foreign books and journals have been reporting the higher results; so that the opinion prevails, that the hard dry anthracite mined in the State will range from 90 to 94 per cent. of fixed carbon in the market product. Such is, however, not the case, as the recent analyses made by Mr. McCreath show.

The results which have been reported in the Rogers and Taylor tables referred to may be taken as those of analyses

of mineralogical specimens, which were in most cases carefully selected, either from the mined coal or from special portions of the bed. In no case, it is believed, are the analyses a guarantee of the character of the coal which was being mined or shipped as fuel from the individual localities at the time that the specimens were collected. Even the samples which were collected in considerable quantity, and analyzed and tested for their evaporative capacity by Johnson for the Government, in 1842, were not, in all cases, fair averages of the coal which could be commanded in the market from the different mines for which his results were reported.

As indications of the composition of mineralogical specimens, the chemical analysis reported by Rogers and Johnson are of little scientific value, without a minute description of the physical characteristics and geological associations of the coal for which they stand. This conclusion could be substantiated by a number of instances to which reference might be made; notably, one where an experienced mining expert was requested to collect duplicate samples from a point in one of the Mammoth bed mines; the two samples when analyzed, showed the following results:

	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.
Specimen No. 1,	2.590	3.858	86.233	0.851	6.448
Specimen No. 2,	2.440	3.998	80.301	0.649	12.612

These two analyses are worthless as indications of the fuel-value of the coal, because it would be unreasonable to suppose that either the first or the second sample, showing such a wide range of composition from the other, could be taken as a fair average of the coal shipped from this mine. Nor are these analyses of scientific value without certain facts connected with the occurrence of the coal at this special point to suggest some reason why such a wide difference should exist.

If the amount of combustible matter in a coal is any cri-

terion of its fuel-value, an examination which has recently been made by the survey shows how ignorant we are as to the actual worth of the different coals which we burn, and how readily we may be deceived by the special characteristics of a coal which we may have noticed, and by which we may have judged of its heating capacity.

In order to test the value to be attached to the judgment of the trade in discriminating between different coals, one of the largest miners and shippers of anthracite coal, who has for a great many years been connected with the mines over a wide area in the region, was requested to name a number of coals which were credited, by most consumers, with about equal value. Samples of these coals were collected from one or two hundred tons, as they were ready to be shipped to market; the amount collected from each analysis ranging in weight from one to two hundred pounds, which was then reduced by the ordinary methods now commonly used in sampling any mineral product for qualitative and quantitative tests. The number of samples obtained in this way was thirty-three, of which Mr. McCreath reported the following analyses.

The table of averages, preceding the table containing the individual analyses, has been compiled from the above analyses; they show the mean character of the coal obtained from the more important coal-beds in the Northern field in the vicinity of Wilkes Barre, in the Eastern Middle (Lehigh) field in the vicinity of Hazleton, in the Western Middle field in the vicinity of Shenandoah, and in the Southern field on the property of the Lehigh Coal and Navigation Company, between Mauch Chunk and Tamaqua.

Average Composition of Pennsylvania Anthracite.

No. of specimens.	Name of Coal Bed.	Name of Coal Field.	Chemical Analyses.						Specific gravity.	Percentage of Constituents of Fuel.		
			Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Total.		Fixed carbon.	Volatile combustible matter.	Carbon ratio. $\frac{C.}{V. H.—C.}$
3	Wharton, . . .	Eastern Middle, .	3.713	3.080	86.404	.585	6.218	100	1.620	96.56	3.44	28.07
5	Mammoth, . . .	Eastern Middle, .	4.119	3.084	86.379	.496	5.922	100	1.617	96.55	3.45	27.99
2	Primrose, ...	Western Middle, .	3.541	3.716	81.590	.499	10.654	100	1.654	95.64	4.36	21.93
5	Mammoth, . .	Western Middle, .	3.163	3.717	81.143	.899	11.078	100	1.657	95.62	4.38	21.83
2	Primrose,? F., †	Southern,	3.008	4.125	87.982	.506	4.379	100	1.584	95.52	4.48	21.32
2	Buck Mountain,	Western Middle, .	3.042	3.949	82.662	.462	9.885	100	1.667	95.44	4.56	20.93
1	Seven Foot, . . .	Western Middle, .	3.410	3.978	80.868	.512	11.232	100	1.651	95.31	4.69	20.32
7	Mammoth, . . .	Southern, . . .	3.087	4.275	83.813	.641	8.184	100	1.631	95.15	4.85	19.62
3	Mammoth, .	Northern, . .	3.421	4.381	83.268	.727	8.203	100	1.575	95.00	5.00	19.00
	B. Coal Bed, ‡ . .	Loyalsock, . . .	1.295	8.100	83.344	1.031	6.230	100	——	91.14	8.86	10.29

* These analyses are arranged in the order of the percentage of fixed carbon in the fuel constituents.

† Called Red-Ash bed in the Panther creek basin.

‡ This coal, according to the classification referred to below, would be called semi-anthracite, on account of its percentages of volatile matter and fixed carbon. The percentage of volatile matter is not as great, however, as that contained in many of the coals from the Shamokin and Lykens Valley Districts, with which the Loyalsock coal favorably compares. The Shamokin and Lykens Valley coals are called anthracites by the trade, and on this basis the trade must consider Loyalsock or Bernice coal an anthracite.

Composition of Pennsylvania Anthracite.

No. of specimens.	Name of Colliery and Coal Bed.	Chemical Analyses.							Physical Properties.		Percentage of Constituents of Fuel.		
		Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Phosphorus.	Total.	Color of ash.	Specific gravity.	Fixed carbon.	Volatile combustible matter.	Carbon ratio $\frac{C}{V.H.C.}$
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
	Northern Coal Field.												
1	Hollenback shaft, No. 2, at Wilkes-Barre, Baltimore (E) bed,	2.493	4.342	83.967	.653	8.544	.010	100	Reddish-gray,	1.614	95.08	4.92	19.33
2	D. & H. C. Co.'s No. 5, at Plymouth, Cooper bed,	3.676	4.516	80.510	.734	10.564	.002	100	Gray,	1.566	94.69	5.31	17.83
3	D. & H. C. Co.'s No. 5, at Plymouth, Bennett bed,	4.092	4.283	85.329	.794	5.502	trace	100	Gray,	1.546	95 23	4.78	19.92
	Eastern Middle Coal Field.												
4	Jeddo, Nos. 3 and 4, at Jeddo, Mammoth bed,	3.862	3.242	85.319	.533	7.044	.005	100	Cream,	1.647	96.34	3.66	26.32
5	Ebervale, No. 2, at Ebervale, Mammoth bed,	4.132	3.346	85.409	.511	6.602	.011	100	Cream,	1.595	96.23	3.77	25.53
6	Coleraine, Nos. 1 and 2, at Coleraine, Wharton bed,	3.728	2.750	86.916	.574	6.032	.001	100	Reddish-gray,	1.621	96.93	3.07	31.57
7	Coleraine, Nos. 1 and 2, at Coleraine, Mammoth bed,	4.304	2.996	86.712	.448	5.540	.017	100	Cream,	1.587	96.66	3.34	28.94
8	Spring Mountain, No. 4, at Jeansville, Mammoth bed,	4.042	2.986	88.201	.387	4.384	.008	100	Cream,	1.651	96.73	3.27	29.58
9	Spring Mountain, No. 4, at Jeansville, Wharton bed,	3.756	3.376	84.727	.331	7.410	trace	100	Reddish-gray,	1.626	96.17	3.83	25.11
10	Spring Brook, No. 5, at Yorktown, Mammoth bed,	4.254	2.946	86.258	.604	6.088	.029	100	Cream,	1.605	96.81	3.19	30.35
11	Spring Brook, No. 5, at Yorktown, Wharton bed,	3.682	3.116	87.569	.451	5.212	.001	100	Light cream,	1.614	96.56	3.44	28.07

	Western Middle Coal Field.													
12	St. Nicholas, at St. Nicholas, Middle Split, Mammoth bed,	2.494	4.040	80.288	.604	12.574	.002	100	Cream, . . .	1.677	95.21	4.79	19.87
13	St. Nicholas, at St. Nicholas, Bottom Split, Mammoth bed,	3.448	3.660	81.816	.798	10.278	.002	100	Reddish-gray, . .	1.662	95.72	4.28	22.36
14	St. Nicholas, at St. Nicholas, Buck Mtn. bed,	2.500	3.956	83.297	.511	9.736	.004	100	Cream, ...	1.654	95.47	4.53	21.06
15	Gilberton at Gilberton Seven-Foot bed,	3.410	3.978	80.868	.512	11.232	.003	100	Cream, ...	1.651	95.31	4.69	20.32
16	" " Buck Mtn. bed,	3.584	3.942	82.026	.414	10.034	.004	100	Cream, ...	1.681	95.41	4.59	20.79
17	Draper, at Gilberton, Mammoth bed,	2.718	3.828	81.298	1.501	10.662	.018	100	Reddish-gray, .	1.666	95.50	4.50	21.22
18	" " Primrose bed,	3.530	3.696	80.805	.511	11.458	.002	100	" " . .	1.646	95.63	4.37	21.88
19	Turkey Run, at Shenandoah, Mammoth bed, . . .	3.510	3.622	79.660	.584	12.624	.010	100	" " .	1.664	95.65	4.35	21.99
20	Kohinoor, at Shenandoah, Mammoth bed, . . .	3.646	3.440	82.655	1.011	9.248	.018	100	" " . .	1.628	96.00	4.00	24.00
21	Kohinoor, at Shenandoah, Primrose bed, ...	3.550	3.736	82.376	.488	9.850	.005	100	" " .	1.662	95.66	4.34	23.04
	Southern Coal Field.													
22	No. 3 } Lehigh Coal and Navigation Co.'s collieries. Panther Creek basin. Mammoth bed, (E,) .	3.036	4.387	85.729	1.018	5.850	. . . .	100	Red, white specks,	1.578	95.15	4.85	19.62
23	" 3 Red Ash bed, (F,) . .	2.930	4.290	88.181	.556	4.043	. . . .	100	Cream, ...	1.574	95.36	4.64	20.55
24	" 4 Mammoth bed, (D and E,)	3.106	4.270	84.442	.492	7.690	. . . .	100	Light cream, . . .	1.615	95.18	4.82	19.75
25	" 5 Mammoth bed, (D and E,)	3.040	4.656	83.706	.542	8.056	. . . .	100	Light cream, . .	1.620	94.73	5.27	17.98
26	" 6 Mammoth bed, (D and E,)	3.656	3.990	86.703	.505	5.146	. . . .	100	Cream, . . .	1.615	95.60	4.40	21.73
27	" 6 Red Ash bed. (F,)	3.086	3.960	87.783	.455	4.716	. . . .	100	Dark cream, . . .	1.595	95.68	4.32	22.15
28	" 8 Mammoth bed, (D and E,)	3.320	3.713	86.611	.423	5.933	. . . .	100	Cream, ...	1.623	95.88	4.12	23.27
29	" 10 Mammoth bed, (D and E,)	2.742	4.247	81.511	.623	10.876	. . . .	100	Gray, ...	1.675	95.05	4.95	19.20
30	" 11 Mammoth bed, (D? and E,) .	2.706	4.684	77.986	.884	13.740	. . . .	100	Reddish-gray, . .	9.688	94.33	5.67	16.64
31	" 10 Mammoth (D and E) Bony coal, No. 1 †	2.733	3.933	83.115	4.23	9.796	. . . .	100	Cream, ...	1.661	95.48	4.52	21.13
32	" 10 Mammoth (D and E) Bony coal, No. 2,	3.033	4.053	84.173	1.423	7.313	. . .	100	Reddish-gray, .	1.647	95.40	4.60	20.74
33	" 10 Mammoth (D and E) Bony coal, No. 3, ...	2.826	4.247	82.083	.458	10.386	. . . .	100	White, ...	1.677	95.08	4.92	19.32

A comparison of these results with those already referred to, as given by Taylor for the Panther Creek basin, shows wide differences. The two Primrose and seven Mammoth samples reported in the table for the Southern field came from the Panther Creek basin; the average of the two Primrose coals indicating 1.29 per cent., and the average of the seven Mammoth specimens 5.4 per cent. less fixed carbon than Taylor's average; the minimum fixed carbon in the Survey's analyses being 78 as against 86 in Taylor's table, and the Survey's maximum being 88 against 92.6.

These results evidently prove: (1,) that the samples which were collected in the past for analyses were not collected with sufficient care; for, with the improvements which have been made in the breaker-machinery, and the greater care exercised in the preparation of coal for market, we might reasonably expect to find the higher percentages in the more recent analyses; and (2,) the necessity of changing the basis upon which Pennsylvania anthracite has been rated in the past.

The analyses given in the above table are of coals from all sizes (mixed) which were shipped from the different collieries. It is found in practice that after the coal is passed through the breaker and screened into different sizes for shipment, the purity of the different sizes, as regards fixed carbon and ash, is very different. This is indicated by the following analyses of specimens collected from the Hauto screen-building of the Lehigh Coal and Navigation Company:

Kind of Coal.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Total.	Color of Ash.
Egg, ...	1.722	3.518	88.489	.609	5.662	100	Light cream.
Stove, . .	1.426	4.156	83.672	.572	10.174	100	Cream.
Chestnut, . .	1.732	4.046	80.715	.841	12.666	100	Cream.
Pea, . .	1.700	3.894	79.045	.697	14.664	100	Cream.
Buckwheat,	1.690	4.058	76.918	.714	16.620	100	Cream.

These coals are separated into different sizes according to

the mesh of the screen over which they pass. The sizes noted in the above table passed over and through sieve-meshes of the following dimensions:

		Inches.		*Inches.*
Broken or grate,	through	4	over	2.5
Egg,	"	2.5	"	1.75
Stove,	"	1.75	"	1.25
Chestnut,	"	1.25	"	.75
Pea,	"	.75	"	.50
Buckwheat,	"	.50	"	.25

In preparing the coal for market, pieces of what is known as *bony coal* are picked out as worthless and thrown on the dirt bank. The luster of this coal is dull, and it has a cannelly appearance; much of it is believed to be as good a fuel coal as that which is shipped from the same colliery to market. In fact, analyses recently made of three specimens* of this bony coal, from a certain colliery, proved them to contain more fuel-constituents than the coal which was sold to the trade.† It has been suggested that the *good* bony coal be called "*cannel anthracite.*"

All the analyses upon which the foregoing statements are based were made subsequent to the writing of the *First Report of Progress*, and are given in detail in the prefatory letter to that report.

In the State report (GG) on the geology of Lycoming and Sullivan counties, a number of analyses of the Bernice or Loyalsock coal are given. The characteristics of this coal have been questioned from time to time, not only by the coal trade, but by analytical chemists, and in order to obtain some proofs as to whether the analyses which have been previously made were of average samples, and indicated the general characteristics of the coal, other samples were collected during the past year, and have just been analyzed by Mr. McCreath, with the following results:

---

*See *First Report of Progress, Anthracite Coal Region*, page 181.

†An incident was recently related to me by a very intelligent miner, where he was severely reproved by a not over-intelligent mine official for calling attention to the fact that much good coal was evidently being thrown away on the waste dump, merely because it had a bony or cannelly appearance.

	"*No. 1.*"	"*No. 2.*"	"*No. 3.*"	"*No. 4.*"
Water at 212° F., . . .	3.670	.976	.654	.650
Volatile matter, . . .	15.420	9.969	9.501	9.405
Fixed carbon, ...	71.341	81.236	79.265	83.691
Sulphur, ...	.594	1.274	.665	.909
Ash, ...	8.975	6.545	9.915	5.345
	100.00	100.00	100.00	100.00
Color of ash.	*Cream.*	*Reddish Gray.*	*White.*	*Gray.*
Carbon-ratio, . . .	1: 4.63	1: 8.15	1: 8.34	1: 8.898

Specimen No. 1 is from what is known as Bed A, which underlies the working seam, and which is not mined. The coal from this bed, which occurs sixty feet below the bed which is mined, is true bituminous,* while the coal from the working seam, and whose composition is shown in the analyses of specimens 2, 3, and 4, and in the table on page 14, is a true anthracite, according to the trade classification, or a semi-anthracite by the classification referred to in the early part of this paper.

The existence of these two beds in nearly horizontal positions, with only sixty feet of rock between them, and under geological conditions more nearly resembling those found in the Pennsylvania bituminous than in the Pennsylvania anthracite region, is unique.

A study of the Bernice anthracite bed and of the underlying bituminous bed in conjunction with a consideration of the geological, physical, and chemical conditions under which the other Pennsylvania anthracites, the Welsh anthracite, and the Belgian bituminous beds exist, would seem to lend support to the belief that the change of the original vegetable deposits into anthracite has probably been effected to a great extent through a chemical process, by which a portion of the carbon has been oxidized, forming carbonic acid, at the expense of the combined oxygen; a portion of the combined hydrogen has been oxidized, forming water; and a portion of the carbon and hydrogen have been com-

* The composition of a specimen of coal recently taken from Bed A at the Meylert opening is quite different from that taken from the Jackson opening, of which No. 1 is an analysis. See chapter on the Loyalsock-Mehoopany Coal-field in this report.

bined, forming marsh-gas. The removal of the marsh-gas (carbureted hydrogen) in this way, as pointed out by Bischof, may convert bituminous coal into anthracite.

The heat, which was unquestionably produced in the main Pennsylvania anthracite fields, during the plication of the strata, has possibly helped the process, and the water, which was held by the strata in their semi-plastic condition at the end of the Carboniferous Period when the plication took place, has probably been a potent aid.* The absence of great convolutions in the strata of the Bernice coal basin would not necessarily invalidate this suggested explanation, since the time at which the Belgian field was plicated and the geological conditions under which it took place, may account for the coal-beds being bituminous rather than anthracite. The existence of two coal-beds, one bituminous and the other anthracite, in the Bernice basin, under the same geological conditions, might be accounted for more readily than the gradual transition of a bituminous bed into an anthracite bed in Wales.

The question has been asked, Why should the coal-beds of the Pennsylvania anthracite basins be more oxidized than those of the bituminous fields? In reply, Professor Lesley suggests this answer: "The undisturbed western coal-measures consist largely of clay strata; those of the eastern coal measures consist in a much larger proportion of sand and gravel. This would favor the superior oxidation of the latter." Another important consideration is the fact that the circumstances, subsequent to and during the time in which the vegetable matter which composed the anthracite beds was accumulated, were probably more favorable to this oxidation. While the plication of the anthracite region would not seem to alone satisfactorily account for the origin of the anthracite character of the coals, yet the time and circumstances under which this plication took place were probably more favorable to the formation of anthracite in Pennsylvania than in Belgium. Many ideas con-

*Daubrée has shown that a small amount of water, raised to a temperature of between 300° and 400° C., may be the cause of rock metamorphism.

nected with this suggested explanation have been thrown out by a number of noted English and American authorities, whom the author hopes to cite in a discussion of this subject to be published in the future, and who are not noted in this brief reference.

In January, 1885, Dr. Charles M. Cresson, consulting chemist of the Philadelphia and Reading Coal and Iron Company, placed at the disposal of the Geological Survey, for publication, a number of analyses which had been made for his company, and which are given below. These analyses are reproduced here from Dr. Cresson's manuscript tables, and they form a valuable contribution to the Survey Report.

Other analyses are now being made, of the average of whole beds, of samples of 300 pounds, which are drawn from the shutes as the coal stands ready for shipment, and Dr. Cresson has offered to give the Survey copies of them as soon as they are finished.

The first table contains analyses of the different benches of coal composing the individual beds for which the analyses stand, and the second table gives the analyses of samples of the coals which were shipped to market from the individual collieries at the time that the analyses were made. The former are of great value as indications of the relative fuel value of the different portions of the several coal-beds, and are important guides to the most economical mining of the coal-beds, in order to obtain the best marketable product with the greatest margin of profit, and the latter are of special interest to consumers.

Analyses of Coals from Six Collieries of the Philadelphia and Reading Coal and Iron Company.

BY DR. CHARLES M. CRESSON.

NAME OF BED.	LOCUST SPRING. Thicknesses of coal-benches.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Heating power.	BOSTON RUN. Thicknesses of coal-benches.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Heating power.	ELLANGOWAN. Thicknesses of coal-benches.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Heating power.
Big Tracy,													2'	5.50	75.21	3 83	15.46	9.63
													2'	6 08	80.08	1.89	12.00	11.66
Orchard,													2'	8 28	81.68	2 73	12.86	10 12
													2'	5 18	85.88	2.61	6.33	10.34
Primrose,													1'	2 90	92.21	1.53	3 36	11.00
													3'	3 02	91.57	1.86	3.60	8.58
													1' 6''	3.84	91 61	1.98	2.63	10.45
													1' 8''	3.73	87.26	2 11	6.90	9.68
	2' 2''	13.75	75 93	1.19	8.17	10 78							1' 8''	2 95	87.75	2.60	6.70	12.43
Mammoth,	2' 6''	4 73	90.32	0.24	3.75	9.90	3'	1.83	90.53	1.14	6.50	11 22	5' 9''	3.57	79.91	2.21	14.31	9.96
	2'	2.85	92.69	0.14	3.95	10.20	2' 6''	2.07	94 97	0.82	2.14	9.24	3' 5''	1.63	94.12	2 30	1.70	10.34
	3' 2''	2.97	87.72	0 20	8.50	10 67	7'	3.13	87.32	2.01	7.54	10.12	9'	7.23	85.64	2.20	4.98	11.10
	3' 0½''	1.77	91 76	0.22	5.42	11.77	3'	3 60	85.23	3 37	7.80	8.58	2'	4 24	75.54	3.99	16 23	9.90
	4' 3''	4 53	90.77	0.15	3.26	10.56	6'	2 97	91.21	1.42	4.40	10.56	9'	2.16	88 37	3.54	5.50	12 70
Seven Foot,							6'	2.66	83.35	1.93	7.06	10.34						
Buck Mtn.,							10'	•3.99	81.51	4.17	10.33	9.68						
	Indian Ridge.						*Mahanoy City.*						*North Mahanoy.*					
							5'	4.53	86.65	4.67	4.15	9.90						
Primrose,							5'	4.68	90.91	2 81	1.60	9.24						
							3'	3.72	90.51	1.67	4.10	0.34						
	7'	3.75	89 64	4.49	2.12	11.22												
	3'	3.62	88.14	5.98	2.81	11.66												
	3'	8 23	84.59	1.98	5.25	10 12												
	4'	4.71	70.70	0.09	14.50	9.68												
Mammoth,	2'	10.21	87.74	0.65	11 40	9.90												
	1' 6''	5 61	59.58	1.93	32.88	7.04	3' 6''	4.67	83 37	1.50	6.46	10.56						
	5'	5.34	89.65	0.17	4 84	10.78	2' 6''	5.01	83.89	5 08	6 02	8.14						
	3'	2.90	89.88	0.25	6.98	10.12	2	6 61	84.34	2.04	7.01	10.56						
	7'	4.87	79.80	4.33	11.00	11.44	6' 6''	3.00	89 77	2.67	4.56	10.56						
Skidmore,														7.38	84.12	1.97	6.55	10.56
Seven Foot,														5.82	76 59	2.39	15.20	4.40
Buck Mtn.,														12 38	71.89	4 65	11.08	7.92

Analyses of Anthracite Coals and of the Ashes of the same from Forty-two Collieries in the Western Middle and Southern Fields.

BY DR. CHARLES M. CRESSON.

NAME OF COLLIERY.	Volatile Matter. To 212° F.	Volatile Matter. To redness.	Volatile Matter. Total.	Fixed carbon.	Sulphur.	Ash.	Phosphorus.	COLOR OF ASH.	Silica.	Alumina.	Iron. (Sesqui Oxide.)	Lime.	Magnesia.	Sulphur.	Phosphorus.	Heating power. Lbs. water evaporated from 1 lb. coal.
Boston Run,	2.50	2.10	4.60	90 276	0.124	5.00	none	. . . .	3.210	1.100	0.520	none	none	0.051	none	9.10
Hammond,	3.40	1.40	4.80	89.657	0.063	5.46	none	. . . .	3.200	1.610	0 460	none	none	0.047	none	10.64
Schuylkill,	3.87	1.33	5.20	85.703	0.667	8.43	trace	Pale reddish gray,	5 200	1.503	0.597	0.100	0.113	0.027	trace	9.79
North Mahanoy,	3.20	1.35	4.55	86.680	0.564	8.20	0.005	Gray,	5.280	1.499	0 571	0 260	none	0 036	0.006	11.11
Elmwood,	2.70	2.55	5.25	86.244	0.376	8.15	none	Reddish gray,	5.210	1.806	0.614	0.160	0.113	0.040	none	10.45
Furnace,	2.80	1.65	4.45	85.774	0.445	9.38	0.001	Pale reddish gray,	5 780	2.516	0.414	0.210	0.101	0.107	0.001	8.70
Conner,	3.14	1.76	4.90	84.571	0.009	10.52	trace	Gray,	6 700	3 246	0.354	0.200	none	0.010	trace	11.11
Plank Ridge,	3.50	1.88	5.38	84.266	0.102	10.25	0.003	Gray,	6.760	2.792	0.428	0.180	none	0.004	0.003	6.50
Knickerbocker,	2.50	1.88	4.38	86 465	0.335	8.82	none	Pink gray,	6 080	1.815	0.855	none	0 011	0.019	none	6 90
Gilberton,	2.47	1.53	4.00	88.232	0.448	7.32	none	Light gray,	5.590	0.262	0.818	0.080	0 004	0.023	none	9.79
Girard,	2.78	1.94	4 72	85.925	0.445	8.91	none	Reddish gray,	6.180	1.479	0.721	0.090	none	0 022	none	8 50
Brookside,	1.54	3.86	5.40	85.636	0.184	8.78	none	Dark yellow brown,	4.810	1.401	1 759	0.020	0.004	0.049	none	8.30
Bear Run,	2 30	0.90	3 20	85 878	1.162	9.76	none	Gray,	6.255	1.485	1.240	0.020	none	0.095	trace	9.79
Preston 3 and 4,	1.76	1.94	3.70	86.732	0.688	8.88	trace	Light red gray,	5 880	1.836	0 815	0 060	none	0.112	trace	10.23
Turkey Run,	2.77	1.23	4.00	88.331	0 619	7.06	trace	Light red gray,	5.790	0.327	0.383	0.240	none	0 064	trace	12.21
Indian Ridge,	2.50	1.88	4.38	86.299	0.721	8.60	none	Light gray,	7.195	0.163	0.593	0.120	0.011	0.075	none	11 77
Shenandoah City,	2.07	1.40	3.47	90.557	0.543	5.43	none	Light gray,	4 067	0.527	0.346	0.170	none	0.067	none	12.21

West Shenandoah, . . .	2.04	0.78	2.80	87.330	0.570	8.30	trace	Light gray, . . .	5 915	1.958	0.379	0.040	none	0.049	trace	11 09
Richardson, ...	3.27	2.13	5.40	84.671	0.047	9.88	0.003	Reddish gray, . .	6.020	2 600	0.830	0.270	trace	0.041	none	10.67
Thomaston, ...	3.40	2.62	6.02	84.495	0.455	9.03	trace	Reddish gray, . .	4.790	1.830	1 920	0 200	trace	0.279	none	10.45
Beechwood, ...	2.80	1.05	3.65	87.145	0.145	9.06	trace	Reddish gray, .	4 520	3 000	1.200	0 150	none	0.137	none	12 21
Pine Forest, ...	2.42	4.28	6.70	84.226	0.051	9.04	0 004	Reddish gray, . . .	5.170	2 000	1.400	0.460	none	0.045	none	10.45
Glendower, ...	2.35	1.70	4.05	88 252	0.004	9.68	0.014	Reddish gray, . .	4.930	2.800	1 520	0.430	none	0.012	none	10.10
Eagle Hill, ...	1.90	1.28	3.18	85.777	0.126	10.90	0.017	Reddish gray, . .	5.910	2 600	1.400	0.760	trace	0.107	none	7.90
Colket, ...	1.70	2.10	3.80	84.652	0 460	11.14	0.008	Gray salmon, . . .	4.940	3.435	0.705	0.640	none	0.307	0.077	8.50
Pyne, ...	1.80	2 02	3.82	86.785	0 300	9.09	0 006	Salmon, ...	3.910	2 606	0.595	0.620	none	0.232	0.006	10 50
Phœnix Park, ...	1.80	1.76	3.56	86.452	0.300	9.68	0.008	Dark salmon, . .	5 010	3 281	0 749	0.440	none	0.249	0.008	10.89
Wadesville, ...	1.90	1.70	3.60	88.680	0.220	7.50	none	Light salmon, . . .	2 620	2 685	0.335	0.750	none	0.203	none	10 67
East Franklin, ...	2.04	2.44	4.48	83.500	0.500	11.52	none	Light salmon, . .	4.300	3.519	0.661	1.430	none	0.462	none	12.98
Mine Hill Gap, ...	2.08	1 84	3.92	87.165	0.292	8.62	0.003	Light gray salmon,	4 760	2.455	0.496	0.240	none	0.121	0.003	9.79
Mt. Carmel Shaft, . . .	2.25	2.17	4.42	86.357	0.873	8.35	trace	Gray, ...	4 640	3 410	0.256	none	none	0 034	trace	12.22
Locust Spring, ...	1.69	2.08	3.77	87 872	0.858	7.50	trace	Pink gray, ...	4.120	2 980	0 378	none	none	0.055	trace	12.66
Potts, ...	1.74	1.11	2.85	87.655	0 625	8.87	none	Pink gray, ...	3.960	3.810	0.269	0 660	none	0.189	none	12.44
Bast, ...	1.91	1.71	3.62	86 481	0 589	9.31	none	Pink gray, ...	4 870	3.720	0.272	0.350	none	0.083	none	11.56
Mahanoy City, ...	2.50	1.68	4.18	88.621	0.085	7.11	0.004	Gray, ...	4 210	2.400	0.273	0.170	none	0.043	0.004	10 90
Bear Run, ...	2 41	1.26	3.67	86.675	0 510	9.14	0.006	Gray, ...	4 950	3.420	0.569	none	none	0.041	0.006	11.12
North Ashland, ...	2.87	2.11	4.98	86.888	0.310	8.12	0.003	Light gray, ...	5 370	2 400	0 199	0.060	trace	0.023	0.003	10.90
Merriam, ...	1.80	2.51	4.31	87.036	0.110	8.54	0 004	Light gray, . . .	5 420	2.400	0.380	0 220	0 009	0.090	0.004	12 76
Preston, No. 1, ...	1.64	1.72	3.36	84.857	0.315	11.45	0.018	Pink gray, ...	6 900	3.300	0.373	0.060	0.005	0.070	0 018	9.02
Pottsville, ...	1.32	1 19	2.51	83.856	0.423	13.20	0 011	Reddish gray, . .	6 800	5.360	0.448	0 370	0.014	0.160	0.011	9.02
Boston Run, ...	. . .	.	. .	. .	. . .	8.16	. .	. . . .	4.960	1.950	0 800	0.140	0.018	0.471	. . .	. :
Hammond, ...	. . .	.		. . .	. . .	11.40	. .	. . . .	6.670	3 108	0.972	0.170	0.025	0.681	. . . .	. . .

Dr. Cresson, in commenting on these analyses at the time that printed proofs of the the tables were submitted to him for examination, says:

"It must not be forgotten that the analyses by benches represent, as fairly as possible, the average constitution of each bench, and that the analyses by collieries represent very fairly the coal as mined for the market."

"The first set of tables were intended to be a guide to the mining operations, and the second set of tables show whether or not the knowledge gained has been followed out in mining by the exclusion of those parts of the *vein* which contribute inferior product."

These results of Dr. Cresson's are of great value to the coal trade, and they would prove of still greater practical utility if information was at hand to publish in conjunction with the analyses, as to the method by which the samples were collected. Reference to this has already been made on page 312, and the details connected with the collection of the specimens by the Survey, for the analyses which have been made by Mr. McCreath, and reported above, are given with minuteness in the First Report of Progress in the Anthracite Coal Region, page xxxiii. It is believed that a knowledge of such details, connected with the sampling of coals, is necessary in order that the trade may make practical use of coal analyses, either in the sale or purchase of coal from special collieries.

Chapter III.

Survey of the Southern Coal-field.

The geological structure of the Southern Anthracite field is, without doubt, more complicated, and its study attended with greater difficulties than that of any other portion of the region. This results from the greater columnar thickness of the Coal Measures, contained within the synclinals, which are generally of less width, in proportion to their depth, than most of the synclinals in other parts of the region; in consequence the dips in the synclinals and along the anticlinals are generally much steeper than elsewhere. These facts are clearly shown in the tables already given in the general description of the Anthracite Region, where the widths and depths of the coal-basins and the thickness of the Coal Measures, and the coal-beds included, are stated.

The only place in the Southern field where the survey has been completed is in the Panther Creek valley, lying between Mauch Chunk and Tamaqua, a description of the geology of which has been published in the First Report of Progress. The original plan was to continue this survey west from Tamaqua, when that east of the same place had been completed. A number of after considerations made it necessary to abandon this plan.

The following is a list and description of the published sheets, which relate to the Southern field:

Mauch Chunk, Mine and Geological Sheet No. I.
Lansford, " " " " " II.
Tamaqua, " " " " " III.

drawn on a scale of 800 feet to 1 inch, $\frac{1}{9600}$th of nature, showing the plan of all the mines in the Panther Creek valley, and the shape of the floor of the Mammoth bed, where mined, and its most probable structure in undeveloped areas, by contour curve lines, 50 feet vertically apart.

ONE TOPOGRAPHICAL SHEET, scale 1,600 feet to 1 inch, $\frac{1}{19200}$th of nature, showing the topography of the surface of the Panther Creek valley, by contour curve lines, 10 feet vertically apart, by R. P. Rothwell, Mining Engineer.

THREE CROSS SECTION SHEETS, scale 400 feet to 1 inch, $\frac{1}{4800}$th of nature, showing the geological structure of the coal basins, by 12 cross sections, &c.

THREE COLUMNAR SECTION SHEETS, showing the thickness and character of the coal measures, scale 40 feet to 1 inch, $\frac{1}{480}$th of nature; of the coal-beds, scale 10 feet to 1 inch, $\frac{1}{120}$th of nature; and of the Carboniferous (Pottsville) Conglomerate, scale 100 feet to 1 inch, $\frac{1}{1200}$th of nature.

THREE MISCELLANEOUS SHEETS as follows:

Sheet No. I, containing a diagram showing the surface area of the Panther Creek Coal-basin, underlaid by the Mammoth bed (E or Top Split) and the actual area of the floor of the coal-bed developed into a horizontal plane, scale 2,400 feet to 1 inch, $\frac{1}{28800}$th of nature; accompanied by tables showing the surface areas of the basin, underlaid by the G and F (Upper and Lower Red Ash,) Mammoth (E,) and Buck Mountain coal-beds, together with the actual area of the floor of each coal-bed in acres and square miles.

Sheet No. II, containing a *preliminary* General Map of the Anthracite Coal-fields of Pennsylvania and adjoining counties, scale $\frac{1}{300000}$th of nature, columnar sections of the coal measures in prominent localities, and a list of the operating collieries and their production in 1881.

Sheet No. III, diagram and tables showing the annual production of anthracite coal in Pennsylvania since 1820, and the amount produced in each region, together with the tonnage of the transporting companies, since 1870, compiled by P. W. Sheafer, Mining Engineer, and John H. Jones, Accountant of the transporting companies.

The general features of the structure of the coal-basins in the Southern field are illustrated by the Nesquehoning

cross-section already given (Fig. 2, page 283). The details of the structure in each locality will be found to differ, of course, from the details in the Nesquehoning section.

A general idea of the columnar structure of the Coal Measures and the relationship of the coal-beds can be gotten from the following two sections; one measured in the vicinity of Tamaqua and the other in the Pottsville district. The relationship of these sections, to others in the anthracite region, is shown on miscellaneous sheet No. 11, in the Panther Creek atlas, (Atlas Southern Anthracite Field, Vol. I, AA.)

*Section in the Panther Creek Basin, at Tamaqua.—Authority: Lehigh Coal and Navigation Company and Geological Survey.**

Upper Red Ash Group.	*Rock.*	*Coal beds.*	*Total.*
1. Interval,	216′		to 216′
2. THIRD UPPER RED ASH COAL-BED,		1′	to 217′
3. Interval,	63′		to 280′
4. SECOND UPPER RED ASH COAL-BED,		3′	to 283′
5 Interval,	106′		to 389′
6. FIRST UPPER RED ASH COAL-BED,		4′	to 393′
7. Interval, *Lower Red Ash Group,* 7. Interval,	158′		to 551′
8. COAL-BED, (SECOND TWIN BEDS)		2′	to 553′
9. Interval, (SECOND TWIN BEDS)	13′		to 566′
10. COAL-BED, (SECOND TWIN BEDS)		2′	to 568′
11. Interval,	128′		to 696′
12. COAL-BED, (FIRST TWIN BEDS)		2′	to 698′
13. Interval, (FIRST TWIN BEDS)	13′		to 711′
14. COAL-BED, (FIRST TWIN BEDS)		2′	to 713′
15. Interval,	38′		to 751′
16. JOCK COAL-BED,		7′	to 758′
17. Interval,	92′		to 850′
18. WASHINGTON COAL-BED,		3′	to 853′
19. Interval,	84′		to 937′
20. G, OR UPPER RED ASH, COAL-BED,		6′	to 943′
21. Interval,	46′		to 989′
22. BONY COAL-BED,		4′	to 993′
23. Interval,	55′		to 1048′
24. F, OR LOWER RED ASH, COAL-BED,		10′	to 1058′
White Ash Group.			
25. Interval,	211′		to 1269′

*See Mine sheet No. III and Columnar Section sheet No. II.

26. E COAL-BED, ...	MAMMOTH COAL BED.		24′	to 1293′
27. Interval, . . .		45′		to 1338′
28. CROSS-CUT COAL-BED,			5′	to 1343′
29. Interval, ...		48′		to 1391′
30. D COAL-BED, ...			12′	to 1403′
31. Interval, ...		122′		to 1525′
32. C COAL-BED, ...			8′	to 1533′
33. Interval, ...		175′		to 1708′
34. COAL-BED, ...				
35. Interval, ...		55′		to 1763′
36. B COAL-BED, ...			9′	to 1772′
37. Interval, ...		115′		to 1887′
38. A COAL-BED, ...			16′	to 1903′
Lykens Valley Group.				
39. Interval, ...		240′		to 2143′
40. UPPER LYKENS VALLEY COAL-BED,			6′	to 2149′
41. Interval, ...		145′		to 2294′
42. LOWER LYKENS VALLEY COAL-BED,			?	
Total thickness of rock, ...		2168′		
" " coal-beds, . . .			126′	
" " coal measures, .				2294′

This section is unlike the section given for the Pottsville basin, inasmuch as it represents the succession of strata in one locality. The measurements were made in and about the mines north of Tamaqua, on the east side of the Little Schuylkill river, and through the Locust Mountain gap, where the entire series of strata, represented in the section, dip away from the Locust Mountain south-west, toward the town of Tamaqua, to a point on the river midway between Elm and Vine streets. Here a reverse dip on the south side of the Panther Creek basin is encountered, the center of the basin or synclinal being located at this point. In other words, if a diamond drill-hole should be started at the point indicated, and drilled in a direction (N. 18° 30′ W.) perpendicular to the strike of the rocks, and at the same time perpendicular to the dip or pitch of the beds, or at an angle of 30 degrees with the horizon, the section here given should show the coal-beds and their distances apart, as they would be found in the drill-hole.*

*The coal-beds at Tamaqua were originally named from A to T; A being the first bed which was known at that time in the Locust Mountain gap going south, and T being the most southern bed which was known to exist in the Sharp Mountain gap. Although it was a well-recognized fact by those who had some understanding of the geology of the Tamaqua section, that the same

Section in the Pottsville Basin—Authority: Philadelphia and Reading Coal and Iron Company.

Belmont Estate, east of Pottsville.	*Rock.*	*Coal beds.*	*Total.*
1. LEWIS COAL-BED,		8′	to 8′
2. Interval,	210′		to 218′
3. SPOHN COAL-BED,		8′	to 226′
4. Interval,	210′		to 436′
5. PALMER COAL-BED,		3′	to 439′
6. Interval,	263′		to 702′
7. CHARLIE POTT COAL-BED,		3′	to 705′
8. Interval,	78′		to 783′
9. CLARKSON COAL-BED,		7′	to 790′
10. Interval,	83′		to 873′
11. SELKIRK COAL-BED,		7′	to 880′
12. Interval,	120′		to 1000′
13. LEADER OF COAL,		3′	to 1003′
14. Interval,	45′		to 1048′
In vicinity of Pottsville Shafts.			
15. PEACH MOUNTAIN COAL-BED,		5′	to 1053′
16. Interval,	60′		to 1113′
17. COAL-BED,		3′	to 1116′
18. Interval,	58		to 1174′
19. LITTLE TRACY COAL-BED,		6′	to 1180′
20. Interval,	198′		to 1378′
21. COAL-BED,		2′	to 1380′
22. Interval,	40′		to 1420′
23. LITTLE DIAMOND COAL-BED,		3′	to 1423′
24. Interval,	122′		to 1545′
25. DIAMOND COAL-BED,		6′	to 1551
26. Interval,	158′		to 1709′
27. LITTLE ORCHARD COAL-BED,		3′	to 1712′
28. Interval,	25′		to 1737′
29. ORCHARD COAL-BED,		4′	to 1741′
30. Interval,	190′		to 1931′
31. PRIMROSE COAL-BED,		8′	to 1939′
32. Interval,	91′		to 2030′
33. HOLMES COAL-BED,		4′	to 2034′
34. Interval,	70′		to 2104′
35. LEADER OF-COAL,		4′	to 2108′
36. Interval,	140′		to 2248′
37. MAMMOTH (TOP SPLIT) COAL-BED,		7′	to 2255′
38. Interval,	15′		to 2270′
39. MAMMOTH (BOTTOM SPLIT) COAL-BED		25′	to 2295′

---

bed at different outcrops and in different basins was assigned different letters, yet the idea that there were actually 20 individual coal-beds, one above the other, at Tamaqua, was quite prevalent. My attention was only recently called to this fact by an engineer in the region, who thought that even now, there were many persons in the coal region who believed in the existence of all of these separate beds.

40. Interval,	60′		to 2355′
41. SKIDMORE COAL-BED,		8′	to 2363′
42. Interval,	72′		to 2435′
43. SEVEN-FOOT COAL-BED,		3′	to 2438′
44. Interval,	80′		to 2518′
45. LEADER OF COAL.			
46. Interval,	25′		to 2543′
47. LEADER OF COAL,		2′	to 2545′
48. Interval,	25′		to 2570′
49. BUCK MOUNTAIN COAL-BED,		8′	to 2578′
Eckert Colliery, Tremont.			
50. Interval,	554′		to 3132′
51. COAL-BED,		2′	to 3134′
52. Interval,	50′		to 3184′
53. COAL-BED,		2′	to 3186′
54. Interval,	55′		to 3241′
55. LYKENS VALLEY COAL-BED,		10′	to 3251′
Total thickness of rock,	3097′		
" " coal-beds,		154′	
" " coal measures,			3251′

The upper part of this section, above the Peach Mountain bed, is located about 14 miles (air-line) east of Tremont, at which point the lower part of the section below the Buck Mountain bed has been measured, while the section between these two beds, (Peach Mountain and Buck Mountain,) measured in the vicinity of the Pottsville shafts, is between Tremont and the Belmont estate—in fact, but a short distance west of the latter locality. The entire section, as it has been compiled and reported to me by Mr. Bard Wells, late Assistant Geologist, may be said to represent fairly the succession and thickness of the strata of the Southern field, but does not necessarily represent what would be absolutely found in any one place by commencing to drill in the Lewis bed and piercing the entire series down to the Lykens Valley coal-bed.

The names assigned to the beds in this section are not universally accepted by the local engineers and geologists in the Southern field. Other systems of naming have been reported, which may ultimately prove preferable to the above. A discussion of this subject is deferred until the final report.

Prior to the year 1858 the Schuylkill region, which has always been considered to include all the Western Middle

Coal-field, and that portion of the Southern Coal-field west of Tamaqua, produced more than one half of all the anthracite coal mined in Pennsylvania. Most of this coal was taken from the Southern field, which was the scene of the most active mining operations, especially in the two decades immediately preceding 1858. Most of this early mining had been done in coal-beds situated above water-level. As much of the coal above water-level became gradually exhausted, it was necessary to mine below this level. When it became necessary for the operators to sink slopes and shafts to obtain coal, those portions of the region were sought where the basins were the shallowest and the dip the flattest; and, in consequence, subsequent to 1858 mining operations were gradually extended throughout the Wyoming, Lackawanna, Mahanoy, Shenandoah, Shamokin, and Lehigh regions.

Mining operations in the Southern Coal-field were gradually abandoned, not because the lands upon which they had been carried on were either exhausted or contained no good coal, but because the coal, dipping at high angles, occurred at considerable depths below the surface, and could not be so economically worked.

The location of the most active developments during the two years preceding 1885, can be best seen from the following table, showing the production of the individual coal-fields:

Field.	*1883. Tons.**	*1883. Percentage.*	*1884. Tons.*	*1884. Percentage.*
Northern Field, . .	16,570,425	48.80	16,411,277	50.28
Eastern Middle Field, .	5,586,397	16.45	5,098,684	15.62
Western Middle Field,	8,552,915	25.19	7,896,049	24.19
Southern Field, . . .	3,161,718	9.31	3,149,471	9.65
Loyalsock Field, . . .	84,376	0.25	86,018	0.26
Total production, .	33,955,831	100.00	32,641,499	100.00

During the time that mining was most extensively carried on in the Southern field, it was mostly in the interest of small corporations or of individual operators, and much of the most valuable information which was obtained, connected not only with these mines, but with the geological

*2,240 pounds.

structure which they encountered, is contained in memoranda, on maps or sections most of which are in the private possession of persons who were connected with this development. This material is being gradually scattered, due either to the lack of present pecuniary interest in the properties to which it relates, on the part of the persons holding it, or to the death of the persons who are sufficiently familiar with the records to explain them.

These facts, together with the intricacies connected with the geological structure, make it desirable that the survey of this interesting region should be continuously prosecuted. The insufficient State appropriation made to the Survey, and the demand for the commencement of work in other coal-fields, already referred to at considerable length, made it necessary to temporarily postpone work in this field, where more work had already been done than in any other one district.

A necessary antecedent to geological work in the Southern field is an accurate topographical map showing the surface features by contour curve lines. It is my purpose to make such a survey and construct such a map on a scale of 600 feet to 1 inch, with contour curve lines 10 feet vertically apart, of the entire Southern Coal-field west of Tamaqua, before making any special geological investigations within this area.

It is hoped that the Legislature of 1887 may make an appropriation sufficient to enable this topographical work to be commenced.

Chapter IV.

Survey of the Western Middle Coal-field.

The survey of the Western Middle Anthracite field was commenced in the vicinity of Mahanoy City and Shenandoah in August, 1880. The area between these two towns was selected as a starting point for the survey in this field on account of the extensive mining which had been carried on in this locality, and the complete shape of the maps and sections made by the engineers of the Philadelphia and Reading Coal and Iron Co., relative to the Mahanoy and Shenandoah mines. At that time a definite plan for carrying on the anthracite survey had not been formed, and it was thought that the necessary studies could be best made here, which would enable me to devise a general plan of work for the entire region.

The map and sections of this territory which were completed by the first of December, 1880, were placed immediately in the engraver's hands for printing, and were subsequently published in Report A², upon the "Causes, Kinds, and Amount of Waste of Anthracite," by Franklin Platt, which was issued early in the year 1881. In the preparation of this map I was aided by my assistants, Messrs. A. W. Sheafer and G. Morris, and by the mining engineers of the Philadelphia and Reading Coal and Iron Co. This map formed a basis of a common plan which was subsequently adopted for mapping the entire region.

In addition to this map, which was published in Report A², a special edition was printed, which was accompanied by a short descriptive pamphlet and freely circulated through the coal-fields, liberal criticism being solicited from mining engineers and coal operators. The map was generally approved, and the plan was commented upon by many of the mining engineers, who accepted it as the best which could be designed for carrying on the work. In July, 1881,

a corps was regularly organized, under my personal direction and under the immediate field supervision of Mr. A. W. Sheafer, who continued in charge of the field party until June, 1882, when he resigned from the Survey, and was succeeded by Mr. Bard Wells, who was in charge of the field party until September, 1885, when he too resigned his commission in order to form more lucrative private connections.

During the last three years Mr. Wells was directly assisted by Mr. H. N. Sims and several field aids. All of these gentlemen have shown a personal interest in the work; and, by their faithful and conscientious methods have accomplished flattering results.

The sheets which have so far been published, and which relate to this coal-field, are contained in the Western Middle Coal-field Atlas, Part I, which is composed of 11 sheets, as follows:

FOUR MINE AND GEOLOGICAL SHEETS, scale 800 feet to 1 inch, $\frac{1}{9600}$th of nature showing the plan of all the mines and the shape of the floor of the Mammoth Bed, where mined, and its most probable structure in undeveloped areas, by contour curve lines, 50 feet vertically apart.

1. No. I, DELANO SHEET, between Delano and Mahanoy City, in Schuylkill county.
2. No. II, SHENANDOAH SHEET, between Mahanoy City, Shenandoah, and Gilberton, in Schuylkill county.
3. No. III, GIRARDVILLE SHEET, in vicinity of Frackville and Girardville, in Schuylkill and Columbia counties.
4. No. IV, ASHLAND SHEET, in vicinity of Ashland, Locust Dale, Centralia and Montana, in Schuylkill, Columbia, and Northumberland counties.

THREE TOPOGRAPHICAL SHEETS, scale 1600 feet to one inch, $\frac{1}{19200}$th of nature, showing the topography of the surface by contour curve lines 10 feet vertically apart.

5. No. I, MAHANOY CITY AND DELANO SHEET, in the vicinity of Quakake Junction, Delano, and Mahanoy City, in Schuylkill county; embraces the area on Mine Sheet No. I.

6. No. II, Shenandoah and Girardville Sheet, in the vicinity of Mahanoy City, Shenandoah, Frackville and Girardville in Schuylkill and Columbia counties; embraces area on Mine Sheets Nos. II and III.
7. No. III, Ashland and Mt. Carmel Sheet, in the vicinity of Ashland, Locust Dale, Centralia, Montana, and Mt. Carmel, in Schuylkill, Columbia, and Northumberland counties; embraces area on Mine Sheets Nos. IV and V.

Four Cross Section Sheets, containing vertical cross sections exhibiting the geological structure of the coal-beds. Scale of sections, 400 feet to 1 inch, $\frac{1}{4800}$th of nature.

8. No. I Sheet contains 4 sections between East Mahanoy tunnel and West Mahanoy City.
9. No. II Sheet contains 5 sections between West Mahanoy City and Mahanoy Plane.
10. No. III Sheet contains 4 sections between Mahanoy Plane and Girardville.
11. No. IV Sheet contains 2 detail and 11 skeleton sections between East Mahanoy tunnel and Locust Dale.

This atlas is incomplete, as it does not contain any sheets of columnar sections, exhibiting either the structure of the coal-beds or of the rocks included between them. Such sheets have been published in the other three atlases relating to the Southern, Eastern Middle, and Northern fields, respectively. During the time that the mine and cross section sheets were being constructed, the Survey corps collected a number of section records, of strata cut in bore holes and tunnels. In addition, many sections of coal-beds were obtained, and wherever positive information was had as to the dip of the strata represented in the sections, the thicknesses of the individual strata were reduced so as to show the absolute thickness of each stratum, perpendicular to the bedding.

Twenty-four rock columnar sections have been constructed of the strata lying between the Pottsville Conglomerate, No. XII, and the highest coal-bed between Ashland and Delano. Eleven of these sections were measured by the Survey corps.

In comparing the sections, which were not measured by the Survey, with each other, a number of inconsistencies were discovered in the naming of the different strata in the several sections; this resulted not from any personal error or lack of proper judgment on the part of the observer by whom the sections were measured on the ground, but from the fact that the different sections were measured by different persons; what has been called sandstone in one section may really be identical with another stratum in an adjoining section, but which has been named sandy slate. In other sections the only distinction which has been made has been between slate and those strata which were composed largely of sand; slaty sandstone, fine sandstone, coarse sandstone, and even conglomerate, all have sometimes been described by the general word "*rock*."

It was not thought wise to deduce any geological conclusions, as to the change in the character of the different strata from point to point, unless the sections could first be gone over in the field, as similar sections have been in other portions of the region, and consistent names could be applied to the stratificationof all the sections.

In the case of the coal-beds, as many as 503 measurements of coal-beds in different localities have been reported to the Survey, by the mining engineers of the different companies. The location in the mines of nearly one sixth of these sections is not definitely known, and in many cases no mention is made as to which is the top or the bottom of the bed.

In some collieries in this region there are places in the mines where the top or bottom bench of the coal-bed does not contain coal that is profitable to mine, and, in measuring sections at these points, it is sometimes the custom of the engineers, to report in their sections only that portion of the bed which is considered to be of mining value. The worthless portions of the bed, above or below the good coal, at certain points sometimes changes in character so quickly, that it is profitable to mine, but a short distance away, portions of the coal-bed not noted in measured sections. Unless it is possible, in all cases, to discriminate between these sec-

tions, and state the entire thickness of the bed from the *top rock* above which there is no coal, down to the *bottom rock* below which there is no coal, it would be unfair to pubish any one section as representative of a colliery, or even a portion of it, except where the boundaries of definite portions of the mine workings, referred to, should be clearly noted.

It has been the purpose of the Survey to extend the investigations in the eastern end of the Western Middle Coalfield to embrace a colliery examination similar to that which was made in the Panther Creek coal-basin, the results of which are published in considerable detail in the First Report of Progress.

Much work has already been done with this object in view, and tables have been constructed showing the surface areas of the different properties in the Western Middle Coalfield between Delano and Ashland, included on Mine Sheets I, II, III, and IV, which are underlaid by the different coalbeds and the areas of the floor of these coal-beds for the individual properties. A map has also been constructed showing all the property lines in this area, with the approximate outcrop of each of the coal-beds contained in the individual properties. After this work was completed, it was expected, that we would have had in our possession a sufficient number of columnar sections of the coal-beds, to permit of a general estimate being made, as to the amount of coal which was originally contained in the areas embraced by each mine sheet, and the amount of coal in the different coal-beds which still remains for mining.

The number of sections of the coal-beds was found to be too few, to supply sufficient information, to permit of an estimate of the average thickness of any one bed under any definite area; and it was, therefore, impossible to extend these investigations, until considerable additional work had been done in the field by the Survey corps, in conjunction with the local mining engineers, whose assistance, in the investigation of such questions, is indispensable. This assistance has always been generously afforded the Survey, whenever it has been requested. It was expected that this

investigation would have been completed during the past field season.

A complete report on the eastern end of this coal-field similar to that which is published, in the First Report of Progress, for the Panther Creek coal-basin could have been prepared for the press, but the small amount of money appropriated by the last Legislature for the Survey made it necessary for the Board of Commissioners to reduce the size of the corps which had been working in this field. It has been deemed wise to delay the publication of the descriptive report on the area embraced within the four mine sheets, which have been published for this field, until it can be made complete. A brief reference to these mine sheets, however, may be of interest and prove useful, prior to the publication of the more detailed report.

The eastern border of Sheet No. I is about one quarter of a mile east of Delano, in Schuylkill county, and Sheets Nos. I, II, III, and IV taken together embrace that portion of the coal-basin westward to a line one sixth of a mile east of Mount Carmel, in Columbia county. These sheets have been so arranged that the north and south borders are continuous straight lines. Within this area are situated the following prominent towns: Delano, New Boston, Mahanoy City, Shenandoah, Gilberton, Frackville, Mahanoy Plane, Ashland, Centralia, Locust Gap and Montana.

The general plan for representing the topography, geology and mining features on these maps is the same as that which has been described in detail in Report I, and calls for no further reference in this place.

Mine and Geological sheet No. I, or that in the vicinity of Delano, on the east, and Mahanoy City on the west, embraces mine workings on the following coal-beds: Holmes, which is sometimes locally called the Primrose; the Top, Middle, and Bottom members of the Mammoth; the Skidmore; Seven-Foot; and Buck Mountain. These beds are all of greater or less local importance in different parts of the area.

The following columnar section, constructed from measurements and observations made in the vicinity of Prim-

rose colliery and the East Mahanoy R. R. tunnel, may be taken as a fair illustration of the general structure of the Coal Measures mapped on this sheet. That portion of the section above the Buck Mountain bed was measured at the Primrose colliery, and reported by the Philadelphia and Reading Coal and Iron Company; and that portion of the section below the Buck Mountain bed was measured by the Survey corps in the East Mahanoy R. R. tunnel. The section is as follows:

General Section of the Coal Measures at Primrose Colliery and in the East Mahanoy R. R. Tunnel.

		Rock.	*Coal.*	*Total.*
1. Slate,		10′		to 10′
2. PRIMROSE COAL-BED,			12′	to 22
3. Sandstone,		133′		to 155′
4. TOP SPLIT,	MAMMOTH COAL-BED.		7′	to 162′
5. Sandstone,	MAMMOTH COAL-BED.	80′		to 242′
6. MIDDLE SPLIT,	MAMMOTH COAL-BED.		8′	to 250′
7. Slate,	MAMMOTH COAL-BED.	21′		to 271′
8. BOTTOM SPLIT,	MAMMOTH COAL-BED.		5′	to 276′
9. Slate and sandstone,		93′		to 369′
10. SKIDMORE COAL-BED,			6′	to 375′
11. Slate and sandstone,		68′		to 443′
12. SEVEN FOOT COAL-BED,			3′	to 446′
13. Slate and sandstone,		32′		to 478′
14. BUCK MOUNTAIN COAL-BED,			11′	to 489′
15. Conglomerate,		431′		to 920′
16. LYKENS VALLEY COAL-BED,			3′	to 923′
17. Conglomerate and Sandstone,		410′		to 1333′
18. Red shale,		15′		to 1348′
Total thickness of rock,		1293′		
" " coal-beds,			55′	
" " coal measures,				1348′

This section, with the three below, will be given in more detail when the report relating to this portion of the region is published. About five sixths of the area covered by Mine Sheet No. I is within the Coal Measures; the area covered by the remaining portions of the sheet contain no coal.

Mine Sheet No. II, or Delano Sheet, relates to the area west of Mahanoy City and in the immediate vicinity of the city of Shenandoah. The area covered by this sheet is very

nearly equal to the area covered by the advance sheet which was published in Report A². The structural geology, embraced by this sheet, is as varied and as interesting as that existing anywhere else in the coal-fields. This structure has been beautifully defined by a model which has been constructed by Messrs. E. B. and O. B. Harden. A photograph of this model was taken and will be published in the special report relating to this basin, in conjunction with a small map exhibiting the structure of the bottom of the Mammoth coal-bed by contour lines drawn 50 feet vertically apart. These illustrations will be similar to those relating to the Panther Creek basin, which have already been published in the First Report of Progress.

This method of studying the geological structure, of highly complicated regions, by means of a model, is one of the most helpful and satisfactory methods of determining the local features of structure. The heliotype of the Panther Creek model, which was published in the First Report of Progress, while it has met with a favorable reception among professional geologists, and is considered to be a great aid to a proper appreciation of the geology of the valley, has proved very unsatisfactory to many mining engineers in the region, but not more so than to myself. The photographs of this latter model were experimented upon by the most experienced photographers in Philadelphia and New York, and the photograph of the Panther Creek model, which has been published, has been judged by experts to be the best result which it was possible to accomplish.

Within the area embraced by Mine Sheet II, there have been mined the following coal-beds: Tracy; Diamond; Orchard; Primrose; Holmes; Top, Middle, and Bottom members of the Mammoth; Skidmore; Seven-Foot, and Buck Mountain: shown in the following general section of the Coal Measures, compiled from measurements made at Ellangowan and Indian Ridge Collieries.

General Section of the Coal Measures at Ellangowan and Indian Ridge Collieries.

			Rock.	*Coal.*	*Total.*
1.	Slate,		5′		to 5′
2.	BIG TRACY BED,			4′	to 9′
3.	Slate and sandstone,		55′		to 64′
4.	DIAMOND BED,			7′	to 71′
5.	Slate and sandstone,		118′		to 189′
6.	LITTLE ORCHARD BED,			3′	to 192′
7.	Slate,		24′		to 216′
8.	ORCHARD BED,			11′	to 227′
9.	Slate,		152′		to 379′
10.	PRIMROSE BED,			8′	to 387′
11.	Slate,		100′		to 487′
12.	HOLMES BED,			13′	to 500′
13.	Slate,		6′		to 506′
14.	COAL,			4′	to 510′
15.	Sandstone,		131′		to 641′
16.	TOP SPLIT,	MAMMOTH BED.		12′	to 653′
17.	Slate,		39′		to 692′
18.	MIDDLE SPLIT,			8′	to 700′
19.	Slate,		22′		to 722′
20.	BOTTOM SPLIT,			15′	to 737′
21.	Slate and sandstone,		21′		to 758′
22.	SKIDMORE BED,			4′	to 762′
23.	Slate and sandstone,		24′		to 786′
24.	SEVEN-FOOT BED,			7′	to 793′
25.	Slate, sandstone, and conglomerate,		71′		to 864′
26.	BUCK MOUNTAIN BED,			12′	to 876′
27.	Sandstone and slate,		12′		to 888′
28.	COAL,			5′	to 893′
29.	Conglomerate and sandstone,		300′		to 1193′
	Total thickness of rock,		1080′		
	" " coal-beds,			113′	
	" " coal measures,				1193′

The section which has been given, as illustrative of Mine Sheet No. I, exploited the same strata represented in the above section. By a comparison of these two sections a number of differences will be observed, not in the thickness of the corresponding intervals, but in the thickness of the coal-beds themselves. Special comment as to this feature is deferred for the forthcoming special report on this district.

Mine Sheet, No. III, or Girardville Sheet, embraces the area surrounding Girardville, and extends from Frackville on the south-east to within about a mile of Ashland. Large areas underlaid by the Mammoth coal-bed on this

sheet, in the vicinity of Girardville, are undeveloped. The prospecting work which has been done has been of such a character as to leave a proper understanding of the general geological structure here still in doubt. The exploration notes of Mr. Heber S. Thompson have been carefully studied in conjunction with field notes in possession of the Lehigh Valley Coal Co. and others. While, no doubt, the structure of the Mammoth coal-bed within this area, which is suggested on this sheet may, by future mining developments, be wrong, yet it is believed that the explanation of the structure probably approximates the actual condition of affairs as closely as the present possession of facts will permit. The principal coal beds which have been mined on this sheet, at different points, are the Orchard; Primrose; Holmes; the Top, and Bottom Members of the Mammoth; and Buck Mountain beds. A general compiled section exhibiting the general columnar structure of the coal measures of the area on this sheet has been constructed from measurements taken at Hammond, Preston No. 2, and Girard Mammoth collieries, as follows:

General Section of the Coal Measures at Hammond, Preston, and Girard Mammoth Collieries.

	Rock.	Coal.		Total.
1. BIG TRACY BED,		7′	to	7′
2. Measures,	185′		to	192′
3. DIAMOND BED,		4′	to	196′
4. Sandstone,	58′		to	254′
5. COAL,		1′	to	255′
6. Sandstone and slate,	16′		to	271′
7. COAL,		1′	to	272′
8. Sandstone,	16′		to	288′
9. LITTLE ORCHARD BED,		6′	to	294′
10. Sandstone,	88′		to	382′
11. ORCHARD BED,		5′	to	387′
12. Sandstone,	63′		to	450′
13. PRIMROSE BED,		3′	to	453′
14. Sandstone and slate,	109′		to	562′
15. HOLMES BED,		10′	to	572′
16. Sandstone and slate,	114′		to	686′
17. MAMMOTH BED,		23′	to	709′
18. Sandstone,	58′		to	767′
19. COAL,		2′	to	769′
20. Slate,	22′		to	791′

21. COAL,		8′	to 794′
22. Slate,	21′		to 815′
23. COAL,		1′	to 816′
24. Sandstone and slate,	55′		to 871′
25. COAL,		2′	to 873′
26. Sandstones and slate,	81′		to 954′
27. BUCK MOUNTAIN BED,		15′	to 969′
28. Slate, sandstone, and conglomerate,	543′		to 1512′
Total thickness of rock,	1429′		
Total thickness of coal-beds,		83′	
Total thickness of coal measures,			1512′

In this section the Mammoth coal-bed is represented by one member, instead of by three members, as in the section compiled for Sheets Nos. I and II.

Mine Sheet No. IV embraces the area in the immediate vicinity of Ashland, Centralia, and Montana. On this sheet have been mined, at different points in different localities, the following coal-beds: Orchard; Primrose; Holmes; Top, Middle, and Bottom members of the Mammoth; Skidmore; Buck Mountain; and Upper Lykens Valley beds. The most extensive mining, however, has been done in the Mammoth bed, and, next to that, in the Buck Mountain bed.

The relative positions of the coal-beds which have been found within the area of the sheet are shown in the following section, constructed from measurements made at Potts' Colliery and the reported record of the bore hole, driven from the face of Bell's tunnel, at Bellmore colliery.

General Section of the Coal Measures at Bell's Tunnel and Potts' Colliery.

	Rock.	*Coal.*	*Total.*
1. Sandstone and slate,	80′		to 80′
2. LITTLE TRACY BED,		3′	to 83′
3. Slate,	25′		to 108′
4. COAL,		1′	to 109′
5. Slate,	70′		to 179′
6. BIG TRACY BED,		6′	to 185′
7. Sandstone,	72′		to 257
8. COAL,		1′	to 258′
9. Slate,	15′		to 273′
10. LITTLE DIAMOND BED,		6′	to 279′
11. Slate,	97′		to 376′
12. COAL,		1′	to 377′

13. Sandstone,	29′		to 406′
14. BIG DIAMOND BED,		6′	to 412′
15. Sandstone and slate,	106′		to 518′
16. BIG ORCHARD BED,		4′	to 522′
17. Slate and sandstone,	19′		to 541′
18. LITTLE ORCHARD BED,		2′	to 543′
19. Sandstone and slate,	139′		to 682′
20. PRIMROSE BED,		8′	to 690′
21. Sandstone,	103′		to 793′
22. HOLMES BED,		5′	to 798′
23. Slate,	11′		to 809′
24. COAL,		2′	to 811′
25. Sandstone and slate,	122′		to 933′
26. MAMMOTH BED,		24′	to 957′
27. Slate and sandstone,	89′		to 1046′
28. SKIDMORE BED,		3′	to 1049′
29. Slate and sandstone,	37′		to 1086′
30. COAL,		1′	to 1087′
31. Slate,	29′		to 1116′
32. COAL,		1′	to 1117′
33. Slate,	14′		to 1131′
34. COAL,		3′	to 1134′
35. Conglomerate,	38′		to 1172′
36. BUCK MOUNTAIN BED,		11′	to 1183′
37. Sandstone and conglomerate,	32′		to 1215′
38. COAL,		3′	to 1218′
39. Slate, sandstone, and conglomerate,	117′		to 1335′
40. COAL,		4′	to 1339′
41. Slate, sandstone, and conglomerate,	84′		to 1423′
42. LYKENS VALLEY BED,		11′	to 1434′
43. Conglomerate and sandstone,	213′		to 1647′
Total thickness of rock,	1541′		
Total thickness of coal-beds,		106′	
Total thickness of coal measures,			1647′

Although this is a general section, it is, probably, as good as any that can be compiled, representing the structure of the measures within the area covered by the sheet, yet many of the detailed features of the section characterize only special localities, as, for instance; the Mammoth coal-bed, which is represented as possessed of one member 24 feet thick in the section, has been proved by mining to be composed in certain localities of three distinct members. This feature is shown on Mine Sheet No. IV and the accompanying cross-section contained in the Western Middle Coal-field Atlas.

In the same Atlas is published a topographical map of

the Western Middle Coal-field, between Quakake Junction and Mount Carmel, which embraces, besides the area covered by the four accompanying mine sheets, other small outlying areas.

This map was compiled from a survey made between 1868 and 1875, for the Lehigh Valley Railroad Co., by Messrs. Stephen and Joseph S. Harris and A. J. Womelsdorf; from a map of the property of the Locust Mountain Coal and Iron Co., constructed by L. A. & S. M. Riley; and from scattered surveys of limited areas made by the Geological Survey corps. The original map in the possession of the Lehigh Valley Railroad Co. was drawn by Mr. A. B. Cochran and furnished the Survey through the courtesy of Mr. Israel W. Morris. The additions which have been made to the original map of the Lehigh Valley Railroad Co. are carefully noted on each sheet. By special request the names of property owners and colliery operators, the location of town plots, land lines, names of creeks, and location of railroad lines, have been represented on this map just as they were found on the original in the possession of the company. This was done so as to perpetuate the names and locations which are referred to in a number of records contemporaneous with this map. On each sheet is given a comparative list of the collieries and operators; each colliery is designated by a certain name and as operated by a certain individual company, on both the topographical and mine map. This list affords a means of comparing the topographical and mine sheets, although some collieries are known by different names on the two sheets.

This map is one of the best topographical maps that has been published by any private corporation in the Anthracite Coal-fields, and, although the topography of certain areas, outside of the limit of the special area of which the company desired accurate topography, would be modified by more extended surveys in these special areas, yet the topography of areas in the interests of the Lehigh Valley Railroad Co. is perfectly reliable, and has not only served a valuable purpose to the company, but will be found of great interest and value to others not directly connected

with the Lehigh Valley Railroad Co., and to whom individual access to the original map is denied. It is to be regretted that other companies have not made similar topographical surveys and had similar maps constructed.

The surface features of all the anthracite basins, which are not already so mapped, should be topographically surveyed by the Geological Survey before any special study is made of the structural geology. It has been impossible for the Geological Survey to make any extended topographical surveys since the last Legislature saw fit not to make any appropriation for carrying on topographical work.

In addition to the work which has been done on the sheets of this coal-field, which are published, the surveys have been extended to the extreme western end of the basin, four miles beyond Trevorton. The map of this western end will be published on four sheets, the two eastern of which are now in the engraver's hands, and the two western are being constructed in the Survey office.

Greater difficulty has been encountered in the Survey work west of Ashland than in that east of the same town. The work has been very much embarrassed by the difficulty of systematizing on one connected sheet the mine maps in the vicinity of Shamokin. It was found necessary to make extended surveys in this section, since many grievous errors were discovered in some of the mine maps now in existence.

Chapter V.

Survey of the Eastern Middle Coal-field.

The survey of the Eastern Middle Coal-field, or what is generally known as the Upper Lehigh region, was commenced under my personal direction, on the first of November, 1881, and was continuously prosecuted by Mr. A. P. Berlin aided by one assistant from that date until July, 1883. Subsequently Mr. Arthur Winslow with one assistant continued the field survey until May, 1884. Both of these gentlemen resigned to engage in other professional work.

After May, 1884, considerable field work was done, both by myself and Mr. O. B. Harden, until the fall of 1884, in order to finish he work which had so nearly been finished by Mr. Winslow.

The survey work in this region has been attended with difficulties which have not been encountered in other sections. The individual coal-basins are narrow and are separated by broad areas, immediately underlaid by the several members of the Pottsville Conglomerate, which contain no coal. In consequence, the mine maps which have been constructed by the mining engineers in the region are very complete, but they are not generally connected with those of adjoining and parallel basins. More extended instrumental field surveys were made here by the Geological Survey corps than would otherwise have been required.

On account of the restricted means of the Survey, the Board of Commissioners, on the first of January, 1884, were obliged to order the survey work stopped in the Lehigh region, and the closing of the Hazleton office, and this only permitted the continuance of such work, in this region, as

was required to publish maps in the vicinity of Drifton and Hazleton, and the surrounding towns.

The surveys were brought up to the first of November, 1884, subsequent to which date the sheets, which had been prepared up to this time, by the Survey, were published in the Atlas of the Eastern Middle Anthracite field, Part I. This atlas contains eight sheets; they relate to that portion of the Lehigh region in the vicinity of Hazleton and Drifton, in Luzerne county, as follows:

TWO GEOLOGICAL AND MINE SHEETS, scale 800 feet to 1 inch, $\frac{1}{9600}$th of nature, showing the plan of all the mines, and the shape of the floor of the most prominent coal-bed, where mined, and its probable structure in undeveloped areas, by contour curve lines, 50 feet vertically apart.

PLATE 1. Drifton sheet, in vicinity of Woodside, Highland, Drifton, Eckley, Jeddo, Ebervale, and Stockton.

PLATE 2. Hazleton sheet, in vicinity of Lattimer, Hollywood, Harleigh, Hazleton, and Mt. Pleasant.

THREE CROSS-SECTION SHEETS, containing vertical cross-sections exhibiting the geological structure of the coal-beds. Scale of sections, 400 feet to 1 inch, $\frac{1}{4800}$th of nature.

PLATE 3. Five sections; through Highland, Eckley, Woodside, Drifton, Jeddo, Stockton, Lattimer, Ebervale, Hollywood, Hazleton, Buck Mountain, and Mt. Pleasant collieries, and through portions of Hazleton, Big Black Creek, Little Black Creek, Cross Creek, and Cranberry basins.

PLATE 4. Sixteen sections; through Highland, Drifton, Lattimer, Milnesville, Hollywood, Eckley, Jeddo, Ebervale, and Harleigh collieries in Big Black Creek, Little Black Creek, and Cross Creek basins.

PLATE 5. Eight sections; through Hazle Brook, Stockton, Diamond, Hazleton, Cranberry, and Crystal Ridge collieries in the Hazleton basin.

THREE COLUMNAR SECTION SHEETS, containing columnar sections showing the Coal Measures cut in bore hole and tunnels. Scale, 40 feet to 1 inch, $\frac{1}{480}$th of nature.

PLATE 6. Twenty-two sections at Woodside, Highland, Drifton, Lattimer, Milnesville, and Hollywood collieries.

PLATE 7. Twenty-four sections at Eckley, Jeddo, Ebervale, and Harleigh collieries, and on Pennsylvania Railroad Company's tract.

PLATE 8. Twenty sections at Wentz's slope, Hazleton, South Sugar Loaf, Crystal Ridge, Cranberry, and Humboldt collieries, and near reservoir south of the Hazleton shops.

The recent publication of these atlas sheets has not permitted sufficient time in which to prepare a special descriptive report relating to them. In consequence, the publication of this special report will have to be delayed until the issue of a future annual report of progress of the Geological Survey, and it is desired in this connection to only refer to the work in the Lehigh region in order to convey a general idea of its progress.

On Mine Sheet No. I there are worked, in different localities, the Mammoth, the Wharton, and Buck Mountain coal-beds.

The following columnar section, which may be taken as illustrative of the stratification of the coal measures, embraces within the area covered by Mine Sheet No. I, or Drifton Sheet, was compiled from the records of Bore-hole No. 8 of the Drifton colliery, and Bore-hole No. 2 of the Lattimer colliery. That portion of the section above the bottom of the Mammoth bed being taken from the records of Bore-hole No. 8, and that portion of the section below the bottom of the Mammoth bed being taken from the records of Bore-hole No. 2. The section is as follows:

General Section of the Coal Measures at Drifton and Lattimer Collieries, Eastern Middle Coal-field, Drifton Mine Sheet.

		Rock.	*Coal Beds.*	*Total.*
Upper part of Bore Hole No. 8, Drifton Colliery.	1. **Surface,**	30′ 9″		to 30′ 9″
	2. **COAL-BED,**		13′ 7″	to 44′ 4″
	3. **Sandstone,**	39′ 4″		to 83′ 8″
	4. **COAL-BED,**		3′ 7″	to 87′ 3″
	5. **Sandstone and slate,**	120′ 6″		to 207′ 9″
	6. **MAMMOTH BED,**		34′ 8″	to 242′ 5″

Bore Hole, No. 2, Lattimer Colliery.

7. Clay, sandstone and slate,	35' 7"		to 278' 0"
8. COAL-BED, . . .		1' 3"	to 279' 3 '
9. Slate and sandstone, . .	34' 3"		to 313' 6"
10. COAL-BED, ...		4' 2"	to 317' 8"
11. Slate and sandstone, . .	25' 9"		to 343' 5"
12. COAL-BED, ...		3' 6"	to 346' 11"
13. Sandstone, ...	70' 6"		to 417' 5"
14. COAL-BED, ...		3' 10"	to 421' 3"
15. Slate, conglomerate, and sandstone, ...	89' 4"		to 510' 7"
16. BUCK MOUNTAIN BED, .		4' 8"	to 515' 3"
17. Slate, conglomerate, and sandstones, ...	80' 6"		to 595' 9"
18. COAL-BED, ...		5"	to 596 2"
19. Sandstone, bone, etc., .	28' 6"		to 624' 8"
20. COAL-BED, ...		2' 3"	to 626' 11"
21. Slate, sandstone, conglomerate, and red shale, .	184' 5'		to 761' 4"
Total thickness of rock, . .	689' 5"		
Total thickness of coal-beds,		71' 11"	
Total thickness of measures,			761' 4"

On Mine Sheet No. II, or the Hazleton sheet, there are mined in different localities the Mammoth, Parlor, Wharton, and Buck Mountain coal-beds.

The relative position of these coal-beds is shown in the following section, which is illustrative of the general stratigraphy embraced within the area covered by this mine sheet. This section was compiled from the records of the bore hole near the boilers at Hazleton Slope, No. 1, and from the records of bore hole, No. 19, at Hazleton Slope, No. 6. That portion of the section above the top of the Mammoth bed is taken from the records of the former bore hole, and that portion of the section below the top of the Mammoth bed is taken from the records of the latter bore hole. The section is as follows:

General Section of the Coal Measures at the Hazleton Collieries, Eastern Middle Coal-field, Hazleton Mine Sheet.

Bore Hole at Boilers, Hazleton Slope No. 1.

	Rock.	*Coal Beds.*	*Total.*
1. Sandstone and slate, etc.,	121' 5"		to 121' 5"
2. COAL-BED, ...		10"	to 122' 3"
3. Sandstone, ...	66' 5"		to 188' 8"
4. COAL-BED, ...		4' 1"	to 192' 9"
5. Sandstone and slate, . .	192' 7"		to 385' 4"

Bore Hole at Hazleton Slope No. 6 Colliery.	6. MAMMOTH BED, ...		30' 7"	to 415' 11"
	7. Sandstone, ...	51' 11"		to 467' 10"
	8. PARLOR BED, ...		5"	to 468' 3"
	9. Sandstone and slate, . .	36' 9"		to 505' 0"
	10. WHARTON BED, ...		8' 9"	to 513' 9"
	11. Slate and sandstone, . .	26' 10"		to 540' 7"
	12. GAMMA BED, ...		4' 4"	to 544' 11"
	13. Slate, ...	11' 8"		to 556' 7"
	14. COAL-BED, ...		1' 5"	to 558' 0"
	15. Sandstone and slate, . .	58' 4"		to 616' 4"
	16. B. BUCK MOUNTAIN BED,		7' 10"	to 624' 2"
	17. Sandstone, slate, and conglomerate, . .	261' 11"		to 886' 1"
	Total thickness of rock, ...	827' 10"		
	Total thickness of coal-beds, . .		58' 3"	
	Total thickness of coal measures,			886' 1"

There are a great many interesting features connected with the structure of that portion of the Lehigh basin covered by these two mine sheets, and with the identification of the coal-beds. These are graphically illustrated by the sheets contained in the atlas, but special reference to them is delayed until the publication of the special detail report.

The systematizing of the columnar sections, published in the atlas, has been based upon all the facts reported to the survey and obtained from personal examination in the field by the survey corps, and from a careful consideration of the different views held by the local geologists and mining engineers. While some of the conclusions stated cannot be accepted as a final solution of the geological structure, yet it is believed that all the conclusions are supported by the facts which are at present known. In consequence, the structure, suggested for the different columnar sections, will no doubt give to some areas more coal than they have been considered to contain, while other areas which have been considered to contain considerable coal, by the identification suggested, may contain less than has been generally credited to them, and in some cases no commercial coal at all.

On the Hazleton Sheet, the portion of the area embraced by the western part of the sheet, and controlled by the Pennsylvania Railroad Company, has been topographically surveyed, and the surface contours are shown on the pub-

lished sheet. This has been done because the topography of the surface is an important aid to the proper understanding of the underlying geological structure, and since the conclusion arrived at by the Survey as to the economical value of this tract for coal purposes, differs widely from that which had previously been held. All the facts which were in the possession of the Survey, bearing upon the geology of this tract, have been published on the mine, columnar, and cross-section sheets.

The land owners, coal operators, and engineers of the Lehigh region have afforded the Survey every facility in their power for carrying on the survey, and have placed at their disposal the mine maps and section records in their possession. Credit for this assistance is given on the individual sheets contained in the atlas; it is impossible to mention in this connection the names of all who have afforded the Survey assistance, but special reference should be made to Mr. Ario Pardee & Sons, and Messrs. Eckley B. Coxe, T. S. McNair and I. A. Stearns.

Although the area covered by the two mine sheets which are published embraces the scene of the most extensive and active development in the Lehigh region, yet they probably do not include one fourth of the area of the Lehigh coal-field. Some sections of the area, of the Lehigh region, into which the State Survey has not as yet been carried are underlaid by the most difficult geology in the coal regions; so that, it is estimated that the survey of this region will require at least four times as much labor, on the part of the Survey, as that which has already been expended on the sheets which have been published.

Possibly there is no region where the results of the Survey would be of such immediate practical importance to coal operators as in the Lehigh region, but the survey of this interesting district cannot be recommenced until more ample appropriations shall be voted by the Legislature for its continuance.

CHAPTER VI.

Survey of the Northern Coal-field.

In the early part of November, 1880, I made a general reconnoissance of the Wyoming valley between Pittston and Shickshinny in order to ascertain the character of the mine maps, sections, and other colliery information in the possession of the coal operators and mining engineers, which the Survey could make use of, in conjunction with their own field surveys, in making a general geological examination of the district. All parties directly connected with the mining of coal in this valley were found to be generously disposed to aid the Survey.

During the latter part of November, 1880, my assistant, Mr. G. Morris, under my direction, made a reduced connected map of the Lehigh and Wilkes Barre Coal Company's workings, and constructed contour curve lines, 50 feet vertically apart, along the surface of thefloor of the Mammoth coal-bed, wherever the bed had been mined, in order to show its geological structure. The mapping, which was thus completed before the close of the year, was the means of securing a general interest on the part of Wilkes Barre citizens in the work of the Survey.

As soon as the appropriation made by the Legislature of 1881 became available, field work was regularly commenced. It was started in August, 1881, under the immediate field direction of Mr. A. W. Sheafer, assistant geologist in ihe the anthracite region. In the latter part of September of the same year Mr. Frank A. Hill was placed in charge of the field corps in the Northern Coal-field. Since then he has superintended the details of the work there under my personal direction.

Mr. Sheafer resigned from the Survey corps in July, 1882. The vacancy caused by Mr. Sheafer's resignation as assistant for the entire field was not filled, and from that time until

July, 1885, I personally directed all the field work in the anthracite region, the responsible superintendence of the details of the work being left to the several assistants who were placed in charge of the field parties.

In July, 1885, Prof. Lesley placed under my general direction the field work of the State Survey, the correspondence, expenditures and accounts, printing, binding, and the distribution of publications, as Geologist in charge, and Mr. Hill was appointed Assistant Geologist in the Anthracite Coal-fields; and, while continuing to direct the details of the work in the Northern field, assumed the superintendence of the details of the field work elsewhere in the region. Mr. Hill has been assisted from time to time by different members of the Survey corps, who, during their term of service, have devoted their entire time to the work in the Northern field, or who have been specially detailed from time to time to special work in this district, as follows:

H. E. Parrish, September, 1881, to April, 1883; W. J. Flick, September to December, 1881; O. B. Harden, May, 1882, to September, 1883; H. I. Moyer, January to March, 1882; T. J. Williams, June, 1883, to February, 1884; Geo. M. Lehman, April, 1884, to date; A. D. W. Smith, August, 1883, to date; John C. Branner, July, 1883, to June, 1885; Clarence R. Claghorn, July, 1884, to June, 1885. Messrs. Charles B. Scott, Baird Halberstadt, Charles Miner, Jinzoo Adachi,* and Teichi Kada,* have each been connected with the work in this field for several weeks at different times.

Shortly after the commencement of the survey of the Northern field a disposition was manifested on the part of some of the operating companies to make a selection, in their office, of the mining records to which the Geological Survey should have access, it being deemed important for the protection of their individual interests, as coal operators, that certain facts should be withheld from the Survey. This applied more particularly to the records of prospect work, and particularly the records of diamond drill bore holes, which, in many cases, had been bored considerably in ad-

***Late assistants of Mr. Benjamin Smith Lyman, Director of the Geological Survey of Japan.**


MINE SHEET N°V.
P
MINE SHEET N°VI.
BARRE
W I

vance of the furthest mine headings, in order to ascertain either the number of coal-beds existing under the area where the holes were drilled, and the thickness of the individual coal-beds, or to obtain information which would throw some light upon the geological structure of the coal-basins, in order to permit of a better planning of the underground workings.

Where these holes were drilled in territory about which very little was certainly known, either by the general public, or, as in many cases has proved to be the fact, by the parties owning adjoining tracts, the records have been *nominally* guarded with the utmost secrecy. All the special reasons connected with a judicious business policy, which determined such a course, on the part of the property owners or coal operators, it is not necessary to mention.

It is readily perceived, however, that probably one of the most important reasons which has dictated such a line of action has been this: Where a company should bore a diamond drill hole at the extreme limits of their property, at a considerable distance from any actual mine workings, and in the immediate vicinity of other properties, owned by other interests, which they might ultimately want to control, either by purchase at a minimum figure or by lease at a minimum rental, if the drill should disclose facts which would lead to a greater valuation of these adjoining properties, of course it might not be considered a good policy that these facts, which had been obtained at a great expense to the company drilling the hole, should be placed in the hands of those from whom they might want to purchase other properties in the future, which would lead these parties to advance the price of the land. Conversely, some of these drill holes might disclose facts which, if made public, would depreciate the value of the property owned by the company drilling the hole, and which they might subsequently want to sell. Such property owners might not make any misrepresentations to prospective purchasers, as to the coal which might be depended upon underlying a given property, yet it might be considered a wiser policy to let the land be sold upon its own merits, as understood by

the prospective purchaser, rather than to supplement the knowledge of such a purchaser by placing in his hands a drill hole which might depreciate the value of the property in the purchaser's estimation.

If the Geological Survey should have consented to pursue its investigations, in areas where important facts were withheld, the results of the Survey would not only have been incomplete, but very erroneous conclusions might have been arrived at, which would ultimately have made the work of the Survey not only an object of censure, but one of ridicule. Duly appreciating this situation of affairs, it was early decided that the Survey should not attempt to do work in any district of the region where the mining records, held in the possession of either individuals or corporations owning land, should be withheld from the Survey corps, when it should be deemed absolutely important by the Survey that these records should be at its command, in order to arrive at reliable and practical results.

After conferences were had with these parties, especially some of the large operating companies, who questioned the policy of permitting the Survey corps free *entrée* to all their mining records, it was decided to issue a circular letter to each Survey assistant, and an abstract of the same to the individuals and operators from whom information was obtained. These letters were as follows:

(Order No. 3, to Survey Assistants.)

907 WALNUT ST., PHILA.,
December 1, 1881.

DEAR SIR: It has been with difficulty, in some cases, that we have obtained free access to and use of all the maps, sections, and other information in the respective offices of the anthracite coal operating companies. The privileges which have been secured have only been obtained by assuring the executive officers of the respective companies that our examination of their material was to be done confidentially, and that no facts should be made public through the Survey publications except such as they would permit. In order to retain the confidence of the corporations and

individuals with whom we shall come in contact, it is necessary that we should exercise the utmost care in commenting upon their plans and operations, and in making public any facts which we shall obtain, prior to their publication in the Survey reports or maps.

I wish no information or facts given to parties who may request them, without my knowledge and permission.

Respectfully yours,

(Signed) CHAS. A. ASHBURNER,
Geologist in Charge.

(General letter to coal companies, operators, mining engineers, etc.)

907 WALNUT ST., PHILA.,
December 16, 1881.

DEAR SIR: Since the commencement of the regular work of the Survey of the Anthracite Coal-fields, I have been requested, by a number of persons, at different times, to furnish them with copies of some of the facts which my corps have obtained from the individual operators and operating companies, or from our own personal examination in the mines.

I have issued an order to all my assistants that the examination of all material (on their part) shall be considered strictly confidential, and that no facts shall be made public, except through the Survey publications. I have cautioned them, in addition, to exercise the utmost care in commenting upon the plans or operations of individuals or corporations with whom they might come in contact. After we shall have our maps and sections completed and ready for publication, it is my plan to submit them, for the approval of the engineer in charge, before placing them in the hands of the printer.

I have deemed it advisable to communicate the general policy of the Survey, in this matter, to those from whom we may obtain any information.

Respectfully yours,

(Signed) CHAS. A. ASHBURNER,
Geologist in Charge.

The adoption of this plan was the means of the Survey securing all the information, which was considered absolutely essential in order to permit the work to be carried on.

The only bore-hole records which were withheld from the Survey were several in the possession of the Lehigh Valley Coal Company and the Delaware, Lackawanna and Western Railroad Company. The procurement of these records was not considered absolutely essential, to a correct understanding of the general geological structure, of the several areas in which the respective holes were drilled, so that the Survey's examinations were extended to include these areas. Records of several of these holes, however, were reported to the Survey by individuals who had no official connection with the companies, who owned the territory where the holes were drilled. These copies were given to the Survey corps without any solicitation on the part of any of its members. In what way these records came into the possession of the individuals who gave them to the Survey it is not known. These records, however, have not been used, except for comparison, since it is the policy of the Survey not to make use of any information which may come into the hands of any of the members of the corps, unless its use and publication shall be authorized by the parties owning the territory to which it relates.

Since no difficulty has been encountered in obtaining all the information which may be desired, in the anthracite region, except in the Northern Coal-field, it has been thought important, that those who are interested in the work of the Survey, should have a clear understanding of the general policy which governs the field corps in their relations with operators and miners, either individual or corporate.

During the progress of the work a number of applications have been made, from time to time, for some of the results of the work, either in the form of tracings of maps and sections or written records, prior to their publication. In order to enable parties to make practical use of the results of the work as early as possible, it became necessary to issue the following order to the members of the corps and to use the

same as a reply to correspondents making special demands upon the Survey. The order was as follows:

907 WALNUT ST., PHILA.,
December 16. 1881.

DEAR SIR: I have had a number of applications from individuals and the engineers of operating coal companies for copies of the maps and sections which have been constructed of their mines by the Geological Survey, and it has become necessary to be governed in such cases by the following order:

The maps and sections which shall be constructed by the Survey will be, prior to their publication, subject to the examination and study of the individuals or officers of the company to whose land and mines they relate, and to others upon the presentation of a written order from the property owners.

Copies of these illustrations may be made by such persons; and, if made for them by a draughtsman in the employ of the Survey, a charge will be made for the time and material required.

Repectfully yours,
CHAS. A. ASHBURNER,
Geologist in Charge.

Many persons, in the anthracite region, who have not come into personal contact with the field party, and who are unfamiliar with the plan of work which has been outlined in detail in the First Report of Progress, have gotten the impression, that the Survey corps are concerned only in redrawing maps constructed by private engineers and preparing them for publication. To remove such an impression it is necessary to say that it would be impracticable for the State to make any survey of the anthracite region unless copies of the maps and sections which have been in process of construction for the past sixty years, which have been made at a cost of millions of dollars, and which could not be duplicated by any survey made by the State—even if the Legislature should see fit to make sufficient appropriations—be used as a basis for the work.

After copies of these maps are, however, obtained by the Survey, it is necessary for them to be extended and supplemented by maps and sections constructed from the original field work of the Survey corps, in order to permit of the different maps being systematized into a connected whole, by the survey of areas between those which have been mapped by the local mining engineers, and of which no surveys have ever been made.

In addition to this original map work, it has been necessary for the Survey corps to construct cross sections, from careful surface measurements connecting all outcrops, from personal examinations, and from survey maps made of the mines. In fact, there is no work connected with the legitimate occupation of a mining engineer and geologist, in mapping the surface or mines, or in the construction of geological cross and columnar sections, which the Survey corps have not been called upon from time to time to engage in.

The amount of field work which has thus been required to be done, by the Geological Survey, in the Northern Coal-field has been so extensive, that the amount of time spent in collecting and copying information from the surveys of others, has consumed only one sixth of the time which has been required for the original examinations and surveys.

The mine sheets in the Northern Coal-field were originally constructed on a scale of 600 feet to 1 inch, but were afterward reduced by photography to the scale of publication, 800 feet to 1 inch. This scale, was adopted, for the original maps, because the lines which were actually surveyed by Mr. R. P. Rothwell, and used by him in the construction of his topographical map of the Wyoming Coal-field, the original of which is now in the possession of the Geological Survey, were used as a base for the mine sheets.

It was found from surveys made by the Survey corps that where Mr. Rothwell had actually run instrumental lines, his surveys and maps were remarkably accurate, but the surface features at any distance from his instrumental lines could not be depended upon. Mr. Rothwell's survey lines were transferred from his original map to the Survey sheets. Tracings were next made of the maps of the indi-

vidual collieries in the possession of the operators or mining engineers. Most of these tracings were made from the original maps, on a scale of 100 feet to 1 inch. These tracings were then reduced, either by photography or pantagraph, to a scale of 600 feet to 1 inch.

If points were found on these reduced individual mine maps, common with points in Rothwell's survey lines, the mine workings, with their accompanying land lines, were transferred directly to their proper positions on the mine sheets. Where two or more points could not be found which were common both to the mine maps and Rothwell's lines, the Survey corps made such field surveys as were required to fit the mine workings on the Survey sheets.

Most of the courses on the mine maps are referred to various magnetic meridians, so that it became necessary to locate a true meridian on the individual mine maps before connecting them. In August, 1881, Prof. C. L. Doolittle, of Lehigh University, determined the latitude and longitude of a point in the Wilkes Barre court house yard, and, in addition, the direction of the true meridian. An effort was made to find the exact position of some of Rothwell's stations in the vicinity of the court house, in order to determine whether there was any variation of the true meridian as determined by Prof. Doolittle and by Mr. Rothwell respectively. In order to make this calculation, it became necessary to re-survey one of Mr. Rothwell's lines, and determine on the ground the position of the line as shown on the map.

Such a line was run, from the Wilkes Barre court house to a point on the Wyoming road near Forty Fort, and from this survey the true meridian line, as determined by Prof. Doolittle, was placed on Mr. Rothwell's original map and on the Survey sheets. The north and south, and east and west block lines, which are placed on these sheets, were laid out by the Survey and referred to the Survey meridian.

The land lines showing the boundaries of the individual properties or of mining tracts, together with such portions of the Warrantee lines which had been located by the mining engineers, were taken from the mine maps. The

Warrantee lines and the land lines which existed on the Rothwell map were found to differ so widely, in position from the same lines on the mine maps, that it became necessary, in order to place the Warrantee and property lines on that portion of the mine sheets which were not covered by the companies' mine maps, to adopt some one map as a standard. These lines in such areas were therefore taken from the official atlas of Luzerne county, compiled by Mr. J. P. Weller.

All the features shown on the mine sheets, which were not taken from Rothwell's survey lines, from the mine maps, or Weller's tract map, were determined by instrumental surveys made by the Survey corps.

The lines contained on the Weller maps have been severely criticised by some of the local surveyors, and the Survey corps discovered a number of errors in them ; in some cases it was impossible to harmonize the Weller lines with those on private maps, which came into our possession. It is believed, however, that the Weller sheets are as reliable as any one map which could be used.

In connecting the different property lines, the corps was much assisted by Mr. William H. Sturdevant, of Wilkes Barre, who is probably more familiar with land lines than any one person in the Wyoming valley, and great reliance can be placed upon his surveys. Mr. Sturdevant constructed a map of Luzerne county, which was printed on a scale of 4950 feet to 1 inch.

The scale of this latter map is so small, however, and so many adjustments of tract and property lines have been made since its publication, that little use could be made of it, except in conjunction with special maps, which Mr. Sturdevant held privately, and which were always generously placed at the disposal of the Survey.

The geological structure of the coal-beds has been defined by contour curve lines, which were drawn along the floor of the different beds, on the tracings of the original mine maps (scale 100 feet to 1 inch); these structural lines were subsequently reduced, with other data, to a map having a scale of 600 feet to 1 inch.

It was the original purpose of the Survey to follow out the plan, which had been followed in the Southern and Western Middle Coal-fields, of contouring the floor of some member of the Baltimore bed, under the entire area of the Wyoming valley, by the system described in detail in the First Report of Progress. This plan, however, was found to be impracticable, since where the valley was covered by alluvial drift, no surface outcrops occurred, and no thorough explorations had been made which would permit of even a hypothetiical structure being suggested for the Baltimore bed.

There are large areas in the valley which are covered by alluvial drift, and no outcrops of the underlying rocks are to be found, and it is of course impossible to surmise a detailed local structure of the coal-beds, except by extensive shafting and drilling. In consequence, it was decided to merely contour the floor of the coal-beds where actual exploitations and explorations had been made, and to define the general geological structure in other areas by tracing on the map the position of the anticlinals, and by constructing general cross-sections extending across the entire valley from the mountain rims of Pocono Sandstone, No. X, on either side. Wherever it has been possible to locate the anticlinals, they are shown on the mine maps by blue lines.

Three general cross-sections of the valley have been partially completed, although they are not ready for publication, as follows:

Section A extends from Hanover colliery, in Hanover township, north 33° 45′ west through the town of Nanticoke and the colliery workings, which supply the coal for Breakers Nos. 1, 2, 4, and 5 of the Susquehanna Coal Company, it crosses the Susquehanna river immediately below the Nanticoke dam, near the north-western end of the section line.

Section B extends from the south conglomerate outcrop of the basin through the foot of the Lower Ashley Plane north 38° west through Richard's Island, immediately west of the Lance shaft, thence nearly along the line separating the property of the Delaware and Hudson Canal Company from that of the Gaylord Coal Company, to the Red Ash outcrop on the north side of the Wyoming valley.

Section C extends through the mine workings of the Mineral Spring colliery north 41° 45′ west, east of and within about 150 feet of Hillman's Island slope, through the Prospect, Hillman, Midvale, Wyoming, and Henry colliery mine workings, and thence between the Forty Fort and Harry E collieries.

Thirteen sheets relating to the western portion of the Wyoming-Lackawanna coal-basin between Wanamie and Mill creek, both in Luzerne county, have been completed and published in the "Atlas Northern Anthracite Field, Part I." They are as follows:

SIX GEOLOGICAL AND MINE SHEETS, scale 800 feet to 1 inch, $\frac{1}{960}$ th of nature. They show the plan of all the mines and the shape of the floor of the most prominent coal-bed, in those mines in which levels have been run, by contour curve lines 50 feet vertically apart. These six sheets are as follows:

PLATE 1. Nanticoke sheet, in vicinity of Nanticoke and Newport.

PLATE 2. Warrior Run sheet, in vicinity of Warrior Run and Hanover; contains also skeleton map between Wilkes Barre and Shickshinny, (scale, 1 mile to 1 inch.)

PLATE 3. Plymouth sheet, in vicinity of Plymouth.

PLATE 4. Ashley sheet, in vicinity of Sugar Notch, Ashley, and South Wilkes Barre.

PLATE 5. Kingston sheet, in vicinity of Kingston, Mill Hollow, and Maltby.

PLATE 6. Wilkes Barre sheet, in vicinity of Wilkes Barre.

THREE CROSS-SECTION SHEETS, containing vertical cross-sections exhibiting the geological structure of the coal-beds. Scale of sections, 400 feet to 1 inch, $\frac{1}{4800}$th of nature.

PLATE 7. Contains ten sections; through Boston, Plymouth No. 1, 2, and 4, Dodson, Gaylord, Avondale, Nottingham, Reynolds, Franklin, and Sugar Notch Nos. 9 and 10 collieries.

PLATE 8. Contains eleven sections; through Maltby, Forty Fort, "Harry E," Black Diamond, Mill Hollow, East Boston, Kingston, Enterprise, Wyoming, Henry, Burroughs, Prospect, and Midvale collieries.

PLATE 9. Contains five sections; through Pine Ridge, Mill Creek, Laurel Run, Conyngham, Baltimore, Diamond, (No. 1,) Hollenback, (No. 2,) Red Ash, Empire Nos. 3 and 4, Stanton, and South Wilkes Barre collieries.

FOUR COLUMNAR SECTION SHEETS, containing columnar sections showing the coal measures cut in shafts, tunnels, and bore holes. Scale, 40 feet to 1 inch, $\frac{1}{480}$th of nature.

PLATE 10. Contains twenty-one sections at Bennett, Pine Ridge, Enterprise, Henry, Wyoming, Oakwood, Prospect, Conyngham, Baltimore, Diamond, Hollenback, Laurel Run, Mineral Spring, Red Ash, and Young's Slope collieries.

PLATE 11. Contains twenty-one sections at Dorrance, Empire Nos. 2 and 4, Kidder, Stanton, South Wilkes Barre, Franklin, Sugar Notch Nos. 9 and 10, Ashley No. 6, Hillman Vein, and Maffet collieries.

PLATE 12. Contains twenty sections at Maltby, Forty Fort, "Harry E," Black Diamond, East Boston, Kingston, Mill Hollow, Plymouth No. 2, and Boston collieries.

PLATE 13. Contains twenty sections at Plymouth No. 4, Lance, Gaylord, Dodson, Wanamie, Alden, Avondale, Chauncey, Nottingham, Susquehanna shafts Nos. 1 and 2, Hanover, and Warrior Run collieries.

Topographical sheets and other illustrations relating to the area covered by the above six geological and mine sheets will appear in additional parts of the Atlas of the Northern Anthracite Field and in future Reports of Progress.

Chapter VII.

Description of the Geological and Mine, and the Columnar Section Sheets, Northern Coal-field.

The facts which are published on the geological and mine, and on the columnar section sheets, contained in the Northern Coal-field Atlas, are represented with such clearness that it would seem unnecessary in this place to make any special reference to them, unless a general statement was made as to the identity of the individual coal-beds which have been developed at the different collieries in this portion of the Wyoming Coal-field.

Great discrepancies and inconsistencies exist in the names which have been assigned to the coal-beds, not only in this region but elsewhere throughout the entire anthracite fields. Names have been erroneously given to certain coal-beds, for numerous and independent reasons at different collieries; sometimes the classification has been based upon the judgment of the coal trade as to the character of the coal produced; sometimes on the similarity of the associated rocks, both as regards their character and the thickness included between an overlying or underlying coal-bed; sometimes on the physical appearance of the entire coal-bed, or the individual portions of the bed, where it has been broken up into different coal-benches, separated by layers of sandstone, slate, or bony coal; sometimes on a systematic study of the geological structure of the coal-basins in which the coal-beds have been found; sometimes on a similarity of chemical composition and the character and amount of ash obtained in actual consumption: still other reasons might be named.

It is the purpose of the Geological Survey, to make a special examination of the individual characteristics of the different coal-beds in all the mines in the Wyoming valley, in order to make estimates, similar to those already made in the Panther Creek basin, (see First Report of Progress,) as

to the amount of coal which was originally contained under definite areas, the amount of coal taken out, and the amount which still remains to be mined. This work has not yet been undertaken in the Northern Coal-field, and it would be presumption on the part of the Survey to enter into a general description of the identity of all the coal-beds, until this examination shall have been made. Special investigations, however, have been made as to the identity of certain beds (1) in order to permit of the construction of the cross-sections contained on the three sheets in the Northern Coal-field Atlas, Part I, and (2) in order to permit of the adoption of colors for representing the mine workings in the different coal-beds on the mine sheets; it being important that all the workings in one bed, on the different sheets, should be represented by one color.

Such general conclusions as would permit of these two objects being accomplished are clearly defined as follows:

1. By the dotted lines connecting one or more coal-beds in the individual columnar sections, with coal-beds in adjoining sections, contained on Columnar Section Sheets I, II, III, and IV of the Northern Coal-field Atlas.

2. By showing the connected structure, in the cross-sections between the different mine workings, shafts, slopes, and bore-holes which are shown on the numerous sections.

3. By common colors assigned to the individual mine workings on the different mine sheets, which have already been referred to.

The character of the strata has only been determined, in those localities where the cross-sections have been shaded. For more definite information, respecting the thickness and character of the coal-beds, and of the strata between them, reference must be made to the Columnar Section sheets.

The positions of the coal-beds are only known, with any certainty, where they are indicated by a heavy line or by two light lines. In the latter case the coal has generally been worked out of the bed, where the section plane intersects it. Where the coal-beds are represented by a single line, their positions are only approximately known.

Although a general description of the identity of the

coal-beds must be temporarily deferred, it seems that it would be useful, to those making a personal study of the atlas sheets, that some general reference should be made here, which may be of assistance in a better understanding of the details contained on the individual sheets.

Below is given a list of the collieries on the Northern Coal-field mine sheets, arranged alphabetically, and the names of the operators, together with the names of the coal-beds which have been explored and the names of those coal-beds which have been practically mined at each colliery.

Name of colliery.	Operator.	Beds proved by colliery workings.	Beds worked.
Avondale, ...	D.L.&W.R.R.Co.,	Ross, ...	Red Ash.
		Red Ash.	
Alden, ...	Alden Coal Co.,	Bennett, ...	Bennett.
		Twin, ...	Twin.
		Ross, ...	Ross.
		Red Ash.	
Baltimore Tunnel,	D. & H. C. Co., .	Baltimore, . . .	Baltimore.
		Ross, ...	Red Ash.
		Red Ash.	
Baltimore Slope, .	D. & H. C. Co., .	Baltimore, . . .	Baltimore.
Bennett, ...	Waddell & Co., .	Cooper, ...	Cooper.
		Bennett, ...	Bennett.
Black Diamond, .	John C. Haddock,	Lance, ...	Cooper.
		Cooper, ...	Bennett.
		Bennett.	
Boston, ...	D. & H. C. Co., .	Lance, ...	Lance.
		Cooper, . . .	Cooper.
		Bennett, ...	Benne t.
Burroughs, ...	L. V. C. Co., . .	Hillman, . . .	Hillman.
Chauncey, ...	T. P. McFarlane,	Four Foot or Ross,	Four Foot or Ross.
		Red Ash, ...	Red Ash.
Conyngham, . . .	D. & H. C. Co., .	K, ...	Hillman.
		J, Seven Foot, or Abbott.	Baltimore.
		I, Kidney or Bowkley.	
		H or Hillman.	
		Baltimore.	
		Ross.	
		Red Ash.	
Diamond, ...	L. & W B. C. Co.,	Hillman, ...	Hillman.
		Baltimore, . . .	Baltimore.
Dodson, ...	Plymouth C. Co.,	Lance, ...	Lance.
		Hillman, ...	Hillman.
		Old Bennett, . .	Old Bennett.
		Five Foot, ...	Baltimore.
		Baltimore.	
Dorrance, ...	L. V. C. Co., . .	Rock, ...	Hillman.
		Abbott.	
		Bowkley.	
		Hillman.	

Name of colliery.	Operator.	Beds proved by colliery workings.	Beds worked.
East Boston, . . .	W.G.Payne & Co.,	Lance, ...	Cooper.
		Cooper, ...	Bennett.
		Bennett.	
		Ross.	
		Red Ash.	
Empire No. 2, . .	L. & W B. C. Co.,	Ross, ...	Red Ash.
		Red Ash, ...	
Empire No. 4, . .	L. & W B. C. Co.,	Kidney, ...	Hillman.
		Hillman, ...	Baltimore.
		Baltimore, . . .	Red Ash.
		Ross.	
		Red Ash.	
Enterprise, ...	Langdon & Co.,	Hillman.	
		Five Foot, .	Hillman.
		Upper Baltimore,	Five Foot.
		Lower Baltimore,	Upper Baltimore.
		Four Foot, . .	Lower Baltimore.
Franklin, ...	FranklinCoal Co.,	Baltimore, . . .	Baltimore.
		Ross, ...	Ross.
		Red Ash, ...	Red Ash.
Fuller, ...	D.L.&W.R.R.Co.,	Six Foot, . . .	Six Foot.
		Eleven Foot, . .	Eleven Foot.
Forty Fort, ...	J. H. Swoyer, . .	Four Foot, . . .	Four Foot.
		Six Foot, . . .	Six Foot.
		Eleven Foot, . .	Eleven Foot.
Gaylord, ...	Gaylord Coal Co.,	Orchard, ...	Five Foot.
		Five Foot, . .	Cooper.
		Cooper, ...	Bennett.
		Bennett, . . .	Ross.
		Checker, ...	Red Ash.
		Ross.	
		Red Ash.	
Hanover No. 17, .	L. & W B. C. Co.,	Six beds with a thickness of 5 feet or more. but unidentified.	3 beds worked unidentified.
"Harry E," . . .	J. H. Swoyer, . .	Baby Tunnel, . .	Baby Tunnel.
		Eleven Foot, . .	Eleven Foot.
		Ross, ...	Ross.
		Red Ash.	
Hartford No. 6, (Ashley.)	L. & W B. C. Co.,	Hillman, ...	Baltimore.
		Baltimore, . . .	Ross.
		Ross, ...	Red Ash.
		Red Ash.	
Henry, ...	L. V. C. Co., . .	Five Foot, .	Upper Baltimore.
		Upper Baltimore,	Lower Baltimore.
		Lower Baltimore.	
Hillman, ...	H.Baker Hillman,	New, ...	New.
		Snake Island, . .	Snake Island.
		Abbott, ...	Abbott.
		Bowkley, ...	Bowkley.
		Hillman, ...	Hillman.
Hillman Vein, . .	Hillman Vein Coal Co.	Hillman, ...	Hillman.
		Leader, ...	Leader.
Hollenback No. 2,	L. & W B. C. Co.,	Seven Foot, . . .	Hillman.
		Kidney, ...	Baltimore.
		Hillman.	
		Baltimore.	

Name of colliery.	Operator.	Beds proved by colliery workings.	Beds worked.
Hollenback, (R. S. Poole,)	R. S. Poole,	Bowkley,	Bowkley.
		Hillman,	Hillman.
Kington No. 1, / " No. 2,	Kingston Coal Co.,	Orchard,	Lance.
		Lance,	Cooper.
		Cooper,	Bennett.
		Bennett,	Ross.
		Ross,	Red Ash.
		Red Ash.	
Lance,	L. & W B. C. Co.,	Hutchison,	Hutchison.
		Lance,	Lance.
		Hillman,	Hillman.
		Old Bennett,	Old Bennett.
		Five Foot,	Five Foot.
		Cooper,	Cooper.
		Bennett,	Bennett.
Laurel Run,	D. & H. C. Co.,	Cooper,	Cooper.
		Bennett,	Bennett.
Maffet,	Hanover Coal Co.,	Ross,	Ross.
		Red Ash,	Red Ash.
Maltby,	L. V. C. Co.,	Four Foot,	Four Foot.
		Six Foot or Cooper,	Six Foot or Cooper.
		Eleven Foot or Bennett,	Eleven Foot or Bennett.
		Nine Foot,	Nine Foot.
		Ross.	
Midvale,	D. & H. C. Co.,	Abbott,	Abbott.
		Bowkley,	Bowkley.
		Hillman,	Hillman.
Mill Creek,	L. V. C. Co.,	Cooper,	Cooper.
		Bennett,	Bennett.
Mill Hollow,	Waddell & Walter.	Cooper,	Cooper.
		Bennett,	Bennett.
		Ross,	Ross.
		Red Ash,	Red Ash.
Mineral Spring,	L. V. C. Co.,	Cooper,	Cooper.
		Bennett,	Bennett.
		Ross,	Ross.
Nottingham, No. 15,	L. & W. B. C. Co.,	Ross,	Ross.
		Red Ash,	Red Ash.
Oakwood,	L. V. C. Co.,	Abbott,	Upper Baltimore.
		Bowkley,	Lower Baltimore.
		Hillman.	
		Upper Baltimore.	
		Lower Baltimore.	
		Six Foot.	
Parrish,	Parrish Coal Co.,	Baltimore,	Baltimore.
		Ross,	Ross.
		Red Ash,	Red Ash.
Pine Ridge,	D. & H. C. Co.,	Cooper,	Cooper.
		Bennett,	Bennett.
Plymouth, No. 2,	D. & H. C. Co.,	Hutchison,	Lance.
		Lance,	Hillman.
		Hillman,	Old Bennett.
		Old Bennett,	Five Foot.
		Five Foot,	Cooper.
		Cooper,	Bennett.
		Bennett.	

Name of colliery.	Operator.	Beds proved by colliery workings.	Beds worked.
Plymouth, No. 3, .	D. & H. C. Co., .	Hillman, . . .	Hillman.
		Old Bennett?	
		Five Foot, . .	Five Foot.
		Cooper, ...	Cooper.
Plymouth, No. 4, .	D. & H. C. Co., .	Bennett, . . .	Bennett.
		Ross, ...	Red Ash.
		Red Ash.	
Plymouth, No. 5, .	D. & H. C. Co., .	Cooper, ...	Cooper.
		Bennett, . . .	Bennett.
Prospect, ...	L. V. C. Co., . .	Bowkley, ...	Cooper.
		Hillman, . . .	Bennett.
		Cooper.	
		Bennett.	
Red Ash, No. 1, .	Red Ash Coal Co.,	Ross, ...	Ross.
		Six Foot, . . .	Six Foot.
		Red Ash, ...	Red Ash.
Red Ash, No. 2, .	Red Ash Coal Co.,	Ross, ...	Ross.
		Six Foot, ...	Six Foot.
		Red Ash, . . .	Red Ash.
Reynolds, ...	L. & W B. C. Co.,	Red Ash, ...	Red Ash.
Salem, ...	Salem Coal Co., .	Buck Mountain,	Buck Mountain.
South Wilkes Barre	L & W B. C. Co.,	Seven Foot, . .	Seven Foot.
		Kidney, . . .	Kidney.
		Hillman, ...	Hillman.
Stanton, ...	L. & W B. C. Co.,	Kidney, . . .	Baltimore.
		Hillman.	
		Lodgement.	
		Baltimore.	
Sugar Notch, No. 10,	L. & W B. C. Co.,	Kidney, ...	Kidney.
		Hillman, . . .	Hillman.
		Baltimore, . .	Baltimore?
Sugar Notch, No. 9,	L. & W B. C. Co ,	Shaft, ...	Shaft.
		Ross, ...	Ross.
		Red Ash,	Red Ash.
Susquehanna collieries,	Susquehanna C. Co.,	Diamond George or I.	
		Orchard Slope, No. 4, or H,	Orchard Slope, No. 4, or H bed.
		Hillman Slope, No. 2, or G,	Hillman Slope, No. 2, or G bed.
		Lance, or Four Foot.	
		Cooper, or F, . .	Cooper, or F.
		Bennett, Forge, or E, ...	Bennett, Forge, or E.
		Twin or D.	
		Ross or C, . .	Ross or C.
		Buck Mountain,	Buck Mountain.
		Red Ash.	
Wanamie, No. 18, .	L. & W B. C. Co.,	Baltimore, . .	Baltimore.
		Ross, ...	Ross.
		Red Ash, . . .	Red Ash.
Wanamie, No. 19, .	L. & W B. C. Co.,	Unidentified beds	Baltimore.
		Baltimore, . .	Ross.
		Ross, ...	Red Ash.
		Red Ash.	
Warrior Run, . . .	A. J. Davis, . .	B, ...	B.
		C, ...	C.
		D, ...	D.
		E, ...	E.

Name of colliery.	Operator.	Beds proved by colliery workings.	Beds worked.
Wyoming, ...	L. V. C. Co., . .	Hillman, ... Five Foot, . . . Upper Baltimore, Lower Baltimore, Four Foot, . .	Hillman. Five Foot. Upper Baltimore. Lower Baltimore. Four Foot.
West End, No. 1, .	West End C. Co.,	Church. Ross, ... Red Ash, ...	 Red Ash. Ross
West End, No. 2, .	West End C. Co.,	Ross, ... Red Ash.	Red Ash.

Nanticoke Mine and Geological Sheet No. III.

This sheet embraces the area in the vicinity of Nanticoke. The names of the coal-beds which have been worked on this sheet, their individual average thicknesses, and the name of the corporation by which they have been mined are as follows:

NAME OF COAL BED.	Average thickness.	Mined by.
Mills, ...	10′	Susquehanna Coal Co.
Hillman, ...	8′	Susquehanna Coal Co.
Bennett,*	7′	Susquehanna Coal Co.
Bennett *	4′ 10″	Alden Coal Co.
Baltimore,*	6′ 2″	Lehigh and Wilkes Barre Coal Co., at Wanamie.
Ross, ...	4′	Susquehanna Coal Co.
Twin, ...	7′ 1″	Alden Coal Co.
Buck Mountain, ...	10′	Susquehanna Coal Co.
Red Ash, ...	8′	Lehigh and Wilkes Barre Coal Co., at Wanamie.

These coal-beds are placed in the table in the order of their geological superposition among the workable beds, the Red Ash bed occurs immediately on top of the Pottsville Conglomerate, No. XII, and the Mills bed is furthest removed from it. The same order in naming the coal-beds is observed in the description of the other mine sheets.

The variability in the thickness of the individual coal-beds, in limited areas, is very great, so that it is impossible

* The correct naming of these Coal-beds has been questioned.

often-times to speak of any one coal-bed having an average thickness over any special area; or is it possible, to get any practical idea of the amount of coal contained in such a bed, unless a definite statement is made as to the amount of slate or bony coal which is interstratified with the good coal.

These thicknesses are of no use for purely local considerations, but will, no doubt, serve to answer many questions which have been frequently asked of the Survey, as to what might be considered, in a general way, an average thickness of certain beds, in defined areas. In addition to the beds which have been enumerated, there are contained within the area embraced by this mine sheet two other well recognized beds, known as the Diamond or George bed and the Lance or Four Foot bed, besides nine or ten small beds, varying from 1 to 3 feet in thickness, which are described under the general term of coal-beds without any special name being assigned to them.

The Dundee shaft, about a mile and a half from Nanticoke, cuts higher coal measures than have been encountered in any other shaft in the Northern Coal-field. The depth of this shaft is reported to be 812 feet, and from the bottom of the shaft it is reported a bore hole was drilled to a depth of 868 feet, making a total thickness of the coal measures, at this point, of nearly 1700 feet. It has generally been considered that the Dundee shaft is located in the deepest part of the Wyoming basin; it is more probable, however, that the deepest part of the basin is a mile, more or less, southeast of the Dundee shaft, and a few hundred yards east of Askam Cross Roads. A section of the Susquehanna Coal Company's shafts, Nos. 1 and 2, may be taken as representing an average section of the coal measures contained on this sheet. (See sheet of columnar sections of the Northern Coal-field accompanying this report.)

The following are elevations of prominent points on Mine Sheet No. III, compiled from various sources, and based upon the datum of the levels of the Lehigh Valley Railroad:

Elevation of Prominent Points on Mine Sheet No. III.

		Feet above tide.
Wanamie Station,	Lehigh and Susquehanna branch P. & R. R. R.	644.2
Alden "		633.5
Lee Mine "		642.7
Nanticoke "		540.0
Nanticoke Station, D. L. & W. R. R.,		538.09
Susquehanna Coal Co. Breaker, No. 3, Susquehanna Coal Co. R. R.,		534.56
Susquehanna Coal Co. Breaker, No. 5,		538.2
WANAMIE (No. 18) COLLIERY, (L. & S. R. R.)		
Head of slope,		644.0
Foot "		558.4
Head of plane, No. 1, (Baltimore coal-bed,)		667.3
Foot " " 1, " "		559.2
Head " " 2, " "		603.9
Foot " " 2, " "		562.6
Head " " 3, " "		597.9
Foot " " 3, " "		559.4
Head " " 4, " "		578.3
Foot " " 4, " "		559.4
Head of inside slope, " "		564.4
Foot " " " "		416.0
Mouth of inside tunnel, (inside,)		559.4
Head of plane No. 1, Ross coal-bed,		690.1
Foot " " " "		567.2
Mouths of Ross drifts on creek,		721.2
Head of No. 4 slope,		673.0
Top of bore hole,		687.5
Bottom of bore hole,		577.0
ALDEN COLLIERY, (L. & S. R. R.)		
Top of shaft,		619.3
Landing of shaft, tunnel to Bennett coal-bed,		397.2
Landing of shaft, Twin coal-bed,		348.1
Tunnel from shaft to Ross and Red Ash coal-beds,		646.5
SUSQUEHANNA COAL CO., (N. & W B. R. R.)		
Top of shaft No. 1, rail surface landing,		588.33
Top of shaft No. 1, top of coping,		587.16
Rail, Hillman landing, No. 1,		208.5
Rail, Bennett landing, No. 1,		47.18
Rail, Buck Mtn. landing, No. 1,		397.97
Head of plane, Bennett bed, (inside,)		135.05
Foot of plane, Bennett bed, (inside,)		59.91
Head of new plane, Bennett bed (inside,)		159.61
Foot of new plane, Bennett bed, (inside,)		54.29
Top of shaft, No. 2,		547.37
Foot of shaft, No. 2,		-43.59
Head of inside slope, Shaft No. 2,		-40.49
Head of slope, No. 1,		532.51

	Feet above tide.
First lift of slope, No. 1,	455.0
Second lift of slope, No. 1,	354.5
Third lift, east of slope, No. 1,	278.27
Third lift, west of slope, No. 1,	255.13
Foot lift, west slope, No. 1,	125.80
Head of slope, No. 2,	604.99
First lift of slope, No. 2,	359.50
Foot of slope, No. 2,	268.5
Mouth of drift to No. 3 slope,	620.93
Head of No. 3 slope,	622.68
First lift of No. 3 slope,	536.0
Second lift of No. 3 slope,	491.0
Third lift of No. 3 slope,	392.5±
Fourth lift of No. 3 slope,	329.5±
Fifth lift of No. 3 slope,	261.5±
Top of slope, No. 4,	553.97
First lift of slope, No. 4,	382.3
Second lift of slope, No. 4,	293.0
Third lift of slope, No. 4,	231.5
Foot lift of slope, No. 4,	169.2
Grand tunnel,	549.01
Tunnel, No. 1,	556.51
Tunnel, No. 4,	520.71
Top of McFarland's shaft,	549.49
Mouth of Chauncey tunnel,	540.85

Warrior Run Mine and Geological Sheet, No. IV.

There have been but two collieries worked on this sheet, the Warrior Run and the Hanover. The Hanover colliery has been abandoned for some time, and the mining records, relating to it, have not been kept with sufficient detail, to permit of definite conclusions as to the character or identity of the beds opened.

A bore-hole has been sunk to the Pottsville Conglomerate north of the Hanover colliery, but it is difficult even to identify the individual beds in the bore-hole with those cut in the water-level tunnel of the colliery. There are seven beds cut in the tunnel, ranging from 4′ 3″ to 13′ 6″ in thickness, and six other seams ranging from 1′ 0″ to 3′ 6″ in thickness.

At the Warrior Run colliery there are four beds worked, B, C, D, and E, respectively. They are shown on the working map as the Red Ash, Ross, Bennett, and Cooper coal-

beds. It is thought, however, that these beds are the Red Ash and Ross divided, and of unusual thickness. This tendency of the beds to split and thicken is developed at the Sugar Notch colliery, just east of Warrior Run. The thickness of the beds at Warrior Run are as follows: B, 10 feet; C, 10 feet; D, 7 feet, and E, 19 feet. The last coal-bed, however, contains a 3′ 9″ bench of fire-clay dividing the main coal-benches. This division, as seen in the workings, is very suggestive of the Ross coal-bed.

The section of the Hanover bore-hole may be taken to be a representative section of the coal measures on this sheet. The coal beds in this section have been numbered from 1 to 8 inclusive, since the identity of the individual beds has not been finally established.

Elevations of Prominent Points on Mine Sheet No. IV.

	Feet above tide.
L. V. R. R.	
Warrior Run Station,	716.5
Newport Station,	1023.0
L. & S. R. R.	
Warrior Run Station,	631.0
Hanover,	654.05
HANOVER COLLIERY, (L. & S. R. R.)	
Mouth of tunnel,	708.1
Head of slope,	720.6
Foot of slope,	258.6
WARRIOR RUN COLLIERY, (L. V. R. R.)	
Head of Red Ash coal-bed slope,	823.0
1st lift of Red Ash coal-bed slope,	720.0
2d lift of Red Ash coal-bed slope,	603.0
3d lift of Red Ash coal-bed slope,	443.0
Foot of Red Ash coal-bed slope,	302.9
Head of Cooper coal-bed slope,	450.9
Foot of Cooper coal-bed slope,	303.7

Plymouth Mine and Geological Sheet No. V.

The area embraced by this sheet lies around the town of Plymouth, which occupies very nearly a central position on the sheet. In this area the following coal-beds have been found:

Name of Bed.	Average thickness.	Mined by.
Hutchison,	6′ 0″	No mining recorded.
Lance,	6′ 0″	Plymouth Coal Co. L. & W B. C. Co. D. & H. C. Co.
Hillman,	10′ 0″	Plymouth Coal Co. L. & W B C. Co. D. & H. C. Co.
Old Bennett,	12′ 0″	Plymouth Coal Co. L. & W B. C. Co. D. & H. C. Co.
Five Foot,	5′ 0″	Plymouth Coal Co. D. & H. C. Co.
Cooper,* } Baltimore bed.	10′ 0″	Plymouth Coal Co. L. & W B. C. Co. D. & H. C. Co. Gaylord Coal Co.
Bennett,* } Baltimore bed.	8′ 0″	Plymouth Coal Co. L. & W B. C. Co. D. & H. C. Co. Gaylord Coal Co.
Ross,	4′ 0″	D. L. & W. R. R. Co. L. & W B. C. Co. Parrish Coal Co. Gaylord Coal Co. D. & H. C. Co. T. P. Macfarlane.
Red Ash,	20′ 0″	D. L. & W. R. R. Co. L. & W B. C. Co. Gaylord Coal Co. D. & H. C. Co. Parrish Coal Co.

The bed which has been most extensively mined is the Red Ash. At the Nottingham, Reynolds, Jersey, and Avondale collieries, all of which lie to the north of the Susquehanna river and west of the town of Plymouth, this bed has been worked almost exclusively. The same bed has been worked to some extent from the Plymouth shaft, No. 4, of the Delaware & Hudson Canal Company and from the Gaylord shaft. The bed seems to reach its maximum thickness and produces the best quality of coal in those areas where the surface of the valley is too low to contain the Baltimore bed.

At some remote period, when the Wyoming valley was underlaid by higher geological strata than at the present time, these strata having been removed by the process of

* Where Bennett and Cooper are together on this sheet, the average thickness is 15 feet.

erosion; the Red Ash bed must have been overlaid by the Baltimore bed at every point, so that the fact of the absence of the latter bed, at the present time, can in itself have nothing to do with the thickness and quality of the Red Ash coal-bed. If it was known, what had been the character of the Baltimore bed in the areas overlying the present Red Ash bed, and from which it has been eroded, it might be found that the Baltimore bed in those areas was thinner than at other points. As a matter of fact, in many areas both in the anthracite and bituminous coal-fields, it has long been known that one or more coal-beds might be thick and contain coal of pure quality in special areas to the sacrifice of the thickness and purity of overlying or underlying beds. This fact can be explained by geological reasons directly connected with the origin of the coal-beds.

The Nottingham colliery, which draws its coal from the Red Ash bed, is noted for the fact that there have been more cars hoisted per day from its shaft than from any one other opening in the anthracite region.

The thickness of the other coal-beds, which have been mined on this sheet, vary to such an extent that it is practically impossible to assign an average thickness to any one of them over special areas. Various views have obtained at different times as to the identification of the coal-beds opened in the Plymouth collieries. The erroneous views which have been held on this point have occasioned financial loss to some of the Plymouth coal operators and gain to others. The general relationship of the coal-beds in the vicinity of Plymouth is shown on Columnar Section Sheet No. IV.

The elevations of a number of prominent points in the Plymouth collieries are given below:

Elevation of Prominent Points on Mine Sheet No. V.

	Feet above tide.
D., L. & W. R. R., (Bloomsburg division.)	
Plymouth Junction,	**542.6**
Plymouth Station,	**535.0**
Avondale Station,	**530.3**

	Feet above tide.
AVONDALE COLLIERY, (D., L. & W. R. R.)	
Head of shaft,	583.6
Foot of shaft,	319.6
Mouth of outside tunnel,	544.2
Head of inside slope,	332.0
First East lift of inside slope,	284.8
First West lift of inside slope,	250.0
Second East lift of inside slope,	227.0
Third East lift of inside slope,	164.8
Second West lift of inside slope,	163.4
Fourth East lift of inside slope,	91.3
Third West lift (bottom) inside slope,	55.9
Head of plane, No. 1,	391.1
First lift of plane, No. 1,	354.6
Foot of plane, No. 1,	325.9
Head of plane, No. 2,	488.1
First lift of plane, No. 2,	430.8
Foot of plane, No. 2,	397.1
Foot of second opening shaft,	254.7
Mouth of Jersey tunnel,	818.0
Head of Jersey slope,	848.0
First lift of Jersey slope,	725.4
NOTTINGHAM COLLIERY.	
Top of shaft,	540.9
Foot of shaft,	175.9
Head of inside slope,	183.0
First lift, West inside slope,	146.9
Second lift, East inside slope,	80.0±
Second lift, West inside slope,	111.4
Third lift, West inside slope,	79.8
Third lift, East inside slope,	38.6
Fourth lift, West inside slope,	49.1
Fourth lift, East inside slope,	5.83
Fifth lift, West inside slope,	5.83
Head of plane, No. 1,	285.0
Foot of plane, No. 1,	180.0
Head of plane, No. 2,	360.0
Foot of plane, No. 2,	287.0
Head of plane, No. 3,	324.0
Foot of plane, No. 3,	267.0
Head of plane, No. 4,	258.0
Foot of plane, No. 4,	225.0
Head of plane, No. 5,	260.2
Foot of plane, No. 5,	226.7
Mouth of inside tunnel to Ross,	182.5
Head of Wright's slope,	533.1
Foot of Wright's slope,	254.0
REYNOLDS COLLIERY, (D. L. & W. R. R.)	
Head of slope,	705.0
First lift of slope,	640.0

	Feet above tide.
Second lift of slope,	596.0
Third lift of slope,	547.5
Foot of slope,	477.0
Mouth of inside tunnel,	704.0
Mouth of inside tunnel to Ross,	481.0
Plymouth Depot bore-hole,	527.6±
DODSON COLLIERY, (D., L. & W. R. R.)	
Top of shaft,	551.0
Hillman landing in shaft,	335.8
Foot of shaft,	152.8
Head of Rock plane,	378.0
Foot of Rock plane,	338.0
Head of p'ane, No. 1, (Hillman,)	456.6
Foot of plane, No. 1, (Hillman,)	379.3
Head of plane, No. 2, (Lance,)	390.0
Foot of plane, No. 2, (Lance,)	340.0
Head of Baltimore plane,	248.6
Foot of Baltimore plane,	158.6
Head of Ba timore inside slope,	157.5
GAYLORD COLLIERY.	
Top of shaft,	599.0
Bennett Landing,	356.0
Ross Landing,	187.0
Red Ash Landing,	36.0
Head of Rock slope,	589.6
Foot of Rock slope,	448.5
Head of plane, No. 1, slope workings,	507.0
Foot of plane, No. 1, slope workings,	449.0
Head of plane, No. 2, slope workings,	602 0
Foot of plane, No. 2, slope workings,	521.0
Head of plane, No. 3, slope workings,	687.0
Foot of plane, No. 3, slope workings,	602.0
Head of plane, No. 4, slope workings,	603.7
Foot of plane. No. 4, slope workings,	460.5
Mouth of inside tunnel to Ross and Red Ash,	450.3
LANCE COLLIERY, (D., L. & W. R. R.)	
Top of shaft,	569.9
Hillman landing,	330.0
Foot of shaft,	52.8
Top of inside slope,	336.0
First lift of inside slope,	277.0
Foot of inside slope,	267.0
Head of rock plane,	358.0
Foot of rock plane,	337.0
Head of Baltimore inside slope,	62.92
Head of plane, No. 1, (Baltimore,)	120.0
Foot of plane, No. 1, (Baltimore,)	65.0
Head of plane, No. 1, (Hillman,)	411.0
Foot of plane, No. 1, (Hillman,)	346.0
Head of plane, No. 2, (Hillman,)	481.0

	Feet above tide.
Head of plane, No. 3, (Hillman,)	556.0
Foot of plane, No. 3, (Hillman,)	492.0
BOSTON COLLIERY, (D., L. & W. R. R.)	
Top of shaft,	654.93
Foot of shaft,	492.2
D. & H. SHAFT, No. 1, COLLIERY, (D , L. & W. R. R.)	
Top of shaft,	552.6
Lance landing,	410.6
Foot of shaft,	239.6
D. & H., No. 2, SHAFT COLLIERY, (D., L. & W. R. R.)	
Top of shaft,	603.0
Foot of shaft,	204.3
D. & H., No. 3, SHAFT COLLIERY, (D., L. & W. R. R.)	
Top of shaft,	630.7
Foot of shaft,	325.3
D. & H., No. 4, SHAFT COLLIERY, (D., L. & W. R. R.)	
Top of shaft,	702.0
D. & H., No. 5, SHAFT COLLIERY, (D., L. & W. R. R.)	
Top of shaft,	610.6
Foot of shaft,	374.6
Head of inside slope,	413.7

Ashley Mine and Geological Sheet, No. VI.

The area embraced by this sheet lies in the immediate vicinity of the town of Ashley, and to the south and west of the city of Wilkes Barre. The coal-beds mined on this sheet are as follows:

Name of bed.	Average thickness.	Mined by.
Kidney,	6 6″	L. & W B. C. Co.
Hillman,	12 0″	L. & W B. C. Co.
Baltimore,	16 0″	L. & W B. C. Co. Franklin Coal Co.
Ross,	12′	L. & W B. C. Co. Franklin Coal Co.
Red Ash, (top member,)	8′+	L. & W B. C. Co.
Red Ash, (bottom member,)	12′+	Franklin Coal Co.

The thicknesses of the coal-beds on this sheet vary considerably between the eastern and western portions. In the eastern half, in the vicinity of Ashley, the identity of the beds with those mined in the vicinity of Wilkes Barre is clearly proven.

The Red Ash bed, in the Ashley and Sugar Notch mine workings, consists of but one well recognized bench of

coal, while elsewhere in the valley it generally consists of two well defined benches separated by slate or sandstone.

The Ross bed has been most extensively mined in the vicinity of Sugar Notch. In the workings in this bed from Shaft No. 9 of the Lehigh and Wilkes Barre Coal Company, the bed has an average thickness of between 12 and 13 feet, between 7 and 8 feet of which is worked from the lower part of the bed. The other part of the bed which is left behind, consisting of coal, bone, and slate, is frequently called the bony bench. The following thicknesses have been measured of the Red Ash bed at several collieries on this sheet:

Empire shaft, No. 2,		Top split,	6' 9"
		Soft sandstone,	34' 8"
		Bottom split,	12' 4"
Franklin,	Upper Tunnel,	Top split,	6' 11"
		Slate,	4' 6"
		Bottom split,	11' 2"
	Bottom Tunnel,	Top split,	8' 10"
		Fire clay,	5' 0"
		Bottom split,	15' 1"
	Mountain Tunnel	Top split,	12' 4"
		Fire clay, slate, and bone,	3' 2"
		Bottom split,	9' 0"
Ashley, (Inside tunnel,)			13' 7"
Sugar Notch,		Shaft level tunnel,	11' 9"
		No. 3, inside tunnel,	8' 8"
Hanover colliery,			11' 4½"

The other coal-beds which are mined have a more constant thickness than the Red Ash bed. But one bench of the Baltimore bed has been worked within the area of this sheet. The elevation of prominent points in the collieries on this sheet are given below:

Elevation of Prominent Points on Mine Sheet No. VI.

	Feet above tide.
L. V. R. R.	
Sugar Notch Station,	666.0
South Wilkes Barre Station,	548.4
L. & S. R. R.	
Ashley Station,	634.15
Sugar Notch Station,	659.65
EMPIRE, No. 2, COLLIERY, (L. & S. R. R.)	
Head of Empire, No. 2, slope,	725.17
Head of Empire, No. 2, shaft,	723.9

	Feet above tide.
Foot of Empire No. 2, shaft,	364.9
Foot of Empire No. 1, (inside) slope, (Red Ash bed,)	—5.0±
South Wilkes Barre Colliery, (L. & S. R. R.)	
Head of shaft,	559.46
Foot of shaft,	—114.04
Stanton (No. 7) Colliery, (L. & S. R. R.)	
Head of shaft,	618.0
Foot of shaft,	—230.4
Head of air shaft,	626.24
Foot of air shaft,	—5.0
Top of bore-hole,	611.0
Foot of bore-hole,	—72.0
Head of slope,	658.0
First lift of slope,	347.0
Second lift of slope,	193.0
Third lift of slope,	—150.0
Foot of slope,	208.0
Tunnel through anticlinal,	—219.8
Franklin Colliery, (L. V. R. R.)	
Head of Long slope,	683.0
First lift of Long slope,	415.0
Second lift of Long slope,	342.0
Third lift of Long slope,	221.0
Fourth lift of Long slope,	50.0
Foot of Long slope,	—103.0
Mouth of Tunnel to Brown's slope level,	692.6
Head of Brown's slope,	693.0
First lift,	547.0
Second lift,	459.0
Third lift,	389.0
Mouth of lower tunnel to Red Ash,	392.5
Ashley (Nos. 6 and 8) Collieries, (L. & S. R. R.)	
First lift of Germania slope,	632.0
Second lift of Germania slope,	588.0
Third lift of Germania slope,	454.0
Head of Old No. 6 slope,	719.0
Foot of Old No. 6 slope,	445.0
Head of No. 3 inside slope,	448.7
Foot of No. 3 inside slope,	267.5
Head of No 6, new slope,	717.8
First lift of No. 6, new slope,	560.3
Second lift of No. 6, new slope,	456.4
Third lift of No. 6, new slope,	373.3
Maffet drift east of Ashley plane,	711.7
Sugar Notch (No. 9) Colliery, (L. & S. R. R.)	
Top of shaft,	692.3
Foot of shaft,	380.3
Head of inside slope, Ross bed,	384.0
First lift of inside slope, Ross bed, east,	328.7
First lift of inside slope, Ross bed, west,	324.0

	Feet above tide.
Foot of inside slope, Ross bed,	115.0
Head of plane,	530.0
Foot of plane,	384.0
Head of plane,	491.0
Foot of plane,	384.0
Mouth of Water-level tunnel,	686.1
Mouth of Red Ash drift, on Sugar Creek,	917.5
Head of Old Jersey slope,	704.0
Mouth of Jersey tunnel,	698.5
SUGAR NOTCH (No. 10) COLLIERY, (L. & S. R. R.)	
Head of Old slope,	698.2
First lift of Old slope,	472.0
Foot of Old slope,	203.8
Head of New slope,	702.0
First lift of New slope,	500.0
Second lift of New slope,	412.0
Foot of New slope,	339.0
North end of long tunnel between Nos. 9 and 10,	412.7

Kingston Mine and Geological Sheet, No. VII.

All the mine workings on this sheet north and west of the Susquehanna river lie between the Kingston mountain, on the north-west side of the valley, and the Delaware, Lackawanna and Western Railroad. The following beds have been mined within the area embraced by this sheet:

Name of bed.*	Average.	Mined by.
Orchard,	4′ 6″	No record of mining.
Lance,	6′ 6″	Kingston Coal Co.
Hillman,	10′ 0″	Kingston Coal Co. L. V. C. Co. A. Langdon & Co.
Five-Foot,	5′ 0″	L. V. C. Co.
Four-Foot,	4′+	J. H. Swoyer.
Six-Foot,	6 +	J. H. Swoyer. L. V. C. Co. D., L. & W. R. R. Co.
Eleven-Foot,	11′	J. H. Swoyer. L. V. C. Co. D., L. & W. R. R. Co.
Cooper,	7′ 6″	L. V. C. Co. Haddock & Steel. W. G. Payne & Co. Kingston Coal Co. A. Langdon & Co. D. & H. C. Co.

*Local names have been used in this list which do not appear on the mine sheet. The names—Six-Foot and Eleven-Foot—are those most generally in local use.

Name of bed.	Average.	Mined by
Bennett, ...	12′	L. V. C. Co. Haddock & Steel. W. G. Payne & Co. Kingston Coal Co. Waddell & Walter. A. Langdon & Co. J. H. Swoyer.
Ross, ...	10′±	L. V. C. Co. J. H. Swoyer. Waddell & Walter. J. H. Swoyer.
Red Ash, ...	9′ 0″	L. V. C. Co. Waddell & Walter. Kingston Coal Co.

The coal-bed known as the Cooper, west of "Harry E" colliery, is called the Four-Foot bed east of the same colliery; where it is called the Cooper bed its average thickness is generally considered to be about eight feet. It is asserted that the Cooper bed in the mine workings from Black Diamond colliery thins rapidly as the line separating the property attached to this colliery from the property attached to the "Harry E" colliery is approached.

The coal-bed which forms the bottom bench of the Baltimore bed west of "Harry E" colliery has been extensively worked, has an average thickness of about 12 feet, and is known as the Bennett bed. East of this colliery this same bed has been locally called the Six-Foot coal-bed, and its average thickness has generally been considered to be 6 feet. There has always been some doubt among the engineers and coal operators as to the identity of the Bennett and Cooper beds west of "Harry E," with the Four-Foot and Six-Foot beds east of the same colliery.*

The only coal-beds which are generally found workable under the Bennett are the Ross and Red Ash beds. A bed has, however, been found at the "Harry E," Forty Fort, and Maltby collieries, which is locally known as the Eleven-Foot bed. As far as developments have been made in this bed it has been found to contain a good deal of bony coal and slate, and it is probable that it would never generally prove

*Based upon comparison suggested on Columnar Section Sheet No. III.

a bed which can be profitably worked. Many have supposed this bed to be identical with the Bennett, but the developments which have recently been made at the Baby tunnel of the "Harry E" colliery, seem to prove beyond doubt that the Eleven-Foot bed underlies what is generally called the Bennett bed.

The Ross coal-bed, although it has been opened at six of the fourteen collieries contained on sheet No. VII, has never been extensively mined at any of them. The most extensive operations on this bed have been at the "Harry E" colliery; the bed averages about 14 feet thick; a considerable portion of this thickness, however, is made up of bony coal and slate. The following section was measured of the bed in the tunnel at "Harry E" colliery:

Top rock.	
Coal,	4′ 1″
Slate,	8′ 0″
Coal,	1′ 8″
Slate,	1′ 7″
Coal,	4′ 3″

Where the bed is broken up, as shown by this section, it is difficult to mine economically; in some places the interval between the top and bottom benches of coal thickens, and the two benches can be mined independently of one another. In the Mill Hollow drifts the Ross bed has been worked as one bed, the individual benches of coal not being so widely separated as at the "Harry E" colliery. The bed will probably average 8 feet thick. Recently the Mill Hollow, East Boston, and Kingston colliery shafts have been sunk to the Ross and Red Ash coal-beds.

The Red Ash coal-bed has been worked within the area on sheet No. VII, at the Kingston and Mill Hollow collieries. This bed is the lowest workable coal-bed in the Wyoming Valley. Its average thickness is probably 9 feet. Mining developments have not gone sufficiently far to prove the practical value of this coal-bed.

In addition to the beds already referred to there are at least six other smaller beds in the vicinity of Kingston. The thickness of the largest bed so far proved is 4 feet. These beds are known by no special names, and they have

not been considered sufficiently thick to be profitably worked. On the south-east corner of Mine Sheet, No. VII, and south of the Susquehanna river, names have been assigned to some of the coal-beds differing from those within the area just referred to. The coal-beds from the Red Ash to the Cooper are, however, known by the same names in both localities. The differences in naming the beds over the Cooper has resulted in a failure to satisfactorily prove the identity of all the beds both north and south of the river.

On the south side of the river the bed immediately above the Upper Baltimore (Cooper) is known as the Five-Foot bed. It is generally found in two distinct benches, an upper bench from 5 to 6 feet thick, and a lower bench from 1 to 2 feet thick, with 5 feet of fire-clay or slate between. This bed has been worked at the Wyoming and Enterprise collieries. Immediately above the Five-Foot bed, on the south side of the river, a coal-bed is found with an average thickness of 10 feet, which is generally known as the Hillman bed, and is generally spoken of as being the first workable bed above the Baltimore bed. On the north side the river, on Mine Sheet, No. VII, the Hillman bed is not known as such. At the Wyoming and Enterprise collieries a coal-bed is found between the Baltimore and the Ross beds, which is locally known as the Four-Foot and Six-Foot bed, according to its thickness in special localities.

The great amount of alluvial drift in the center of the Wyoming valley, between Kingston and Wilkes Barre, forming what is generally known as the Kingston Flats,* will always have an important bearing upon the mining of coal under this area. This is referred to at considerable length in Mr. Hill's detail report on the Buried valley between Pittston and Nanticoke.

The following elevations of prominent points in the mines on Sheet No. VII have been compiled from various sources:

---

*Valuable coal-beds exist underneath these flats, which, in time, will undoubtedly be extensively worked to the north and south of the river. Several gangways have already been driven across the river under these flats from the mine workings of the Prospect shaft.

Elevation of Prominent Points on Mine Sheet No. VII.

	Feet above tide.
D., L. & W. R. R.	
Kingston Station,	562.3
Bennett Station,	553.1
Maltby Station,	558.2
L. V. R. R.	
Plainsville Station, (main line,)	546.5
B. M. Maltby breaker wall, (Coxton branch,)	567.122
PROSPECT COLLIERY.	
Head of No. 2 slope, (inside,)	98.0
WYOMING COLLIERY.	
Top of shaft,	555.2
Foot of shaft,	305.0
Head of Nanckevles slope, (inside,)	308.5
Foot of Nanckevles slope, (inside,)	183.5
Head of New slope, (inside,)	308.5
Foot of New slope, (inside,)	94.0
Head of 2d New slope, (inside,)	96.7
First lift of 2d New slope, (inside,)	62.0
Head of Merritt's slope, (inside,)	305.6
Gangway in Upper Baltimore bed, same slope,	204.0
Gangway in Lower Baltimore bed, same slope,	152.5
Gangway in Four Foot bed, same slope,	67.9
Head of Five Foot bed slope,	555.0±
HENRY COLLIERY, (L. V. R. R.)	
Top of shaft,	592.4
Foot of shaft,	206.7
Top of air shaft,	595.0
Foot of air shaft,	237.4
Head of main slope,	209.7
First lift of main slope,	147.5
Second lift of main slope,	121.7
Third lift of main slope,	114.2
Fourth lift of main slope,	166.2
Fifth lift of main slope,	149.6
Sixth lift of main slope,	39.1
Seventh lift of main slope,	33.0
Eighth lift of main slope,	28.5
Ninth lift of main slope,	—10.4
Tenth lift of main slope,	— 5.7
Head of plane, No. 1,	248.7
Foot of plane, No. 1,	211.6
Head of plane, No. 2,	260.0
Foot of plane, No. 2,	215.6
Head of plane, No 3,	348.5
Foot of plane, No. 3,	238.2
Head of plane, No. 6,	447.7
Foot of plane, No. 6,	394.0

	Feet above tide.
BURROUGHS COLLIERY, (abandoned.)	
Top of shaft,	563.0±
Foot of shaft,	477.5±
Top of inside slope,	477.5±
Foot of inside slope,	396.0±
ENTERPRISE COLLIERY, (L. V. R. R.)	
Top of shaft,	615.75
Foot of shaft,	244.7
Head of Hillman slope,	617.0±
Head of Upper plane,	539.5
Foot of Upper plane,	457.0
Head of Lower plane, Upper Baltimore bed,	429.8
Foot of Lower plane, Lower Baltimore bed,	250.0
KINGSTON COLLIERIES, (D. L. & W. R. R.)	
Top of No. 1 shaft,	571.0±
Foot of No. 1 shaft,	200.0±
Top of No. 2 shaft,	743.4±
Top of No. 3 shaft,	711.8±
Foot of No. 3 shaft,	165.8±
Top of No. 4 shaft,	568.6±
EAST BOSTON COLLIERY, (D. L. & W. R. R.)	
Head of shaft,	569.5
Foot of shaft, Bennett Landing,	323.2
Head of Bennett slope,	324.6
First lift of Bennett slope,	262.9
Second lift of Bennett slope,	225.6
Third lift of Bennett slope,	190.6
Fourth lift of Bennett slope,	150.6
Fifth lift of Bennett slope,	116.4
Head of Cooper slope,	380.6
First lift,	320.3
Second lift,	293.3
Third lift,	234.8
Head of Rock plane,	376.4
BLACK DIAMOND COLLIERY, (D. L. & W. R. R.)	
Top of shaft,	588.5
Foot of shaft,	357.5
Head of Bennett slope, (inside,)	365.6
First lift of Bennett slope, (inside,)	326.0
Second lift, East Bennett slope, (inside,)	308.9
Fourth lift, East Bennett slope, (inside,)	270.4
Fourth lift, West Bennett slope, (inside,)	257.7
Fifth lift, East Bennett slope, (inside,)	217.9
Fifth lift, West Bennett slope, (inside,)	211.1
Foot of Bennett slope, (inside,)	173.8
MILL HOLLOW COLLIERY, (D. L. & W. R. R.)	
Top of shaft,	643.34
Bennett Landing in shaft,	438.5
Foot of shaft, top slate of Ross,	232.0

	Feet above tide.
Mouth of Lower Ross drift,	631.8
Mouth of Upper Ross drift,	800.8
Mouth of Lower Red Ash drift,	632.4
Mouth of Middle Red Ash drift,	732.6
Mouth of Upper Red Ash drift,	801.2
"HARRY E" COLLIERY, (D. L. & W. R. R.)	
Top of shaft,	674.5
Foot of shaft,	434.0
Head of inside slope,	439.5
Basin of inside s ope,	357.0±
Anticlinal axis, inside slope,	376.0
Head of inside plane,	582.3
Foot of inside p ane,	466.0
Mouth of tunnel,	679.6
Head of Ross slope, (inside,)	684.3
First lift of Ross slope, (inside,)	581.3
Second lift of Ross slope, (inside,)	520.3
Third lift of Ross slope, (inside,)	464.3
Mouth of Baby tunnel,	678.2
Head of Baby tunnel slope,	679.3
First lift of Baby tunnel slope,	634.3
Second lift of Baby tunnel slope,	579.1
FORTY FORT COLLIERY, (D. L. & W. R. R.)	
Top of shaft,	622.7
Landing in shaft, Six-Foot bed,	526.2
Landing in shaft, Eleven-Foot bed,	422.6
Head of inside slope, Eleven-Foot bed,	427.5
Mouth of drift, Four-Foot bed,	621.5
Mouth of Mt. Thomas drift,	883.5
Mouth of drift, Two-Foot bed,	1282.0±
Head of slope, Six-Foot bed,	648.5
Foot of slope, Six-Foot bed,	605.3
MALTBY COLLIERY, (L. V. R. R., Coxton branch.)	
Head of shaft, No. 1,	612.0±
Head of shaft, No. 2,	632.9
Foot of shaft, No. 2,	355.2
FULLER COLLIERY, (D. L. & W. R. R.)	
Top of shaft,	585.0±
Foot of shaft,	400.0±

Wilkes Barre Mine and Geological Sheet, No. VIII.

More active mining operations have been carried on within the area embraced by this sheet than anywhere else in the Northern Coal-field. The coal-beds which have been mined on this sheet are as follows :

Name of bed.	Average thickness.	Mined by.
New.	——	H. B. Hillman.
Snake Island, ...	6′ 0″	H. B. Hillman.
Abbott, ...	6′ 0″	H. B. Hillman. L. V. C. Co.
Bowkley, ...	7′ 0″	H. B. Hillman. L. V. C. Co. L. & W B. C. Co.
Hillman, ...	12′ 0″	H. B. Hillman. R. S. Poole. D. & H. C. Co. Hillman Vein Coal Co. L. V. C. Co. L. & W B. C. Co.
*Baltimore, ...	18′ 0″	L. V. C. Co. L. & W B. C. Co.
Where divided,		
Upper Baltimore, ...	9′ 6″	D. & H. C. Co.
Lower Baltimore, ...	6′ 6″	A. Langdon & Co.
Ross, ...	——	L. V. C. Co. (?) Red Ash Coal Co.
*Red Ash.	14′ 0″	L. & W B. C. Co.
Where divided, ...	——	Red Ash Coal Co.
Top member, ...	7′ 0″	D. & H. C. Co.
Bottom member, ...	12′ 0″	

The New bed has been driven into at the Hillman colliery. Its thickness is not known. The Snake Island bed has also only been worked at this colliery, and its average thickness has been considered to be 6 feet. It is difficult to assign an average thickness to any of the other beds named above, since the mine workings in them have been so extensive, and spread over such a considerable area, that the thickness of any one bed, or thickness of coal contained in any bed, varies considerably between extreme points.

Between the Baltimore and Hillman beds there are generally found two thin coal seams which have nowhere proved workable. At the Hillman Vein shaft these leaders were mined into and the lower one was for some time considered to be the representative of the Hillman bed, and the coal represented by the Hillman was called the Seven-Foot bed. The average thickness of this leader was 4 feet.

The Baltimore bed attains its maximum development, both as to the thickness of its individual benches and the

*The Baltimore bed and the Red Ash bed, on Mine Sheet No. VIII, are divided in places, so that the top and bottom members in each case are distinctly separate.

purity of the coal which they contain, in the vicinity of Wilkes Barre, and, up to the present time, it has been most extensively mined within the area embraced by Mine Sheet No. VIII.

The Baltimore mines, where the bed was originally opened, and from which it received its name, lie directly to the east of Wilkes Barre. The outcrop of this bed has been actually proven from the west head branch of Mill creek, about a mile south of Miner's Mills borough, south-westward to Solomon's Gap; and, it will not be many years before the bed will be mined in, from one side of the Wyoming valley to the other, so that an explorer can go into the mines at Solomon's Gap and come out at Kingston, the distance between the two points in a straight line being five miles.

The average thickness of the Baltimore bed, where it is not divided into two benches, may be considered to be about 18 feet.

From the western edge of Mine Sheet No. VIII, northeast of Baltimore slope, No. 3, a distance of over two miles, the bed is worked as one bench. On the fifth lift gangway of this slope it begins to divide into two benches. At the foot of the new slope the slate separating the two benches of coal is 1 foot thick. About 200 feet west of this slope the slate begins to increase in thickness, until, at a point 50 feet west of the "Flick" line, the slate is 10 feet in thickness, and the two benches of the Baltimore bed are worked separately as two distinct beds of coal, and this is the case in all the collieries to the east of Baltimore slope on Mine Sheet No. VIII. The Upper Baltimore bed will probably average 9′ 6″ in thickness, while the Lower Baltimore, or Bennett bed will probably average 6′ 6″ inches. In the vicinity of Pine Ridge and Laurel Run collieries, a small bed is found, immediately under the Lower Baltimore bed, and is considered to be a split from the latter; it is locally known as the Checker bed.

The Four-Foot coal-bed, which is found in the measures under the Baltimore, has been worked at the Wyoming colliery and a hauling-way has been opened in it at the Oakwood colliery. This bed, as far as known, attains its

maximum thickness at the Oakwood shaft, where it measured 5′ 5″.

The Ross coal-bed has been mined to a limited extent at scattered points within the area of Mine Sheet No. VIII. At the Red Ash collieries its average thickness is 9 feet. For the entire sheet, its average thickness, however, would probably not exceed 7 feet. The Red Ash coal-bed has recently been extensively mined in the most eastern coal-basin on Mine Sheet No. VIII, at the Red Ash and Baltimore Tunnel collieries. The bed is 14 feet thick, and at the Empire colliery has been found to be composed of two distinct members, separated by 34 feet of sandstone, the upper member being 6′ 9″ thick and the lower one 12′ 6″ thick.

Numerous explorations have been made for coal in the Pottsville Conglomerate strata, which immediately underlie the Red Ash bed, and in which the Lykens Valley beds have been found in the Southern field. Along the Wilkes Barre mountains the Pottsville Conglomerate, between the bottom of the Red Ash coal-bed and the top of the Mauch Chunk Red Shale, No. XI, will average about 100 feet thick. On the Ashley planes the Conglomerate was measured by Mr. Arthur Winslow, and was reported 240 feet thick. In this conglomerate, at several points in the southern mountain rim of the Wyoming valley, a coal-bed has been found which is locally known as Bed A. Its thickness ranges from 1 inch to 12 inches. Sufficient explorations have been made in the Wyoming valley to warrant the assertion that no coal-bed of workable thickness containing coal commercially valuable will be found underlying the Red Ash coal-bed.

Below are the reported elevations of a number of prominent points within the area covered by Mine Sheet No. VIII:

Elevation of Prominent Points on Mine Sheet No. VIII.

	Feet above tide.
L. V. R. R.	
Wilkes Barre Old Station,	549.0
Wilkes Barre New Station,	553.5
Wilkes Barre New Station water-table,	554.489
Mill Creek Station,	563.0

	Feet above tide.
Hillman Vein breaker on rail,	566.4
Hillman breaker on rail,	572.0
L. & S. R. R.	
Wilkes Barre Station,	550.03
Pine Ridge Switch,	595.5
Gardner's Switch,	597.0
EMPIRE, No. 4, COLLIERY, (L. & S. R. R.)	
Head of No. 1 slope,	685.0
Foot of No. 1 slope,	500.0
Head of No. 4 slope,	331.0
Foot of No. 4 slope,	187.0
Head of No. 4½ slope,	184.0
Foot of No. 4½ slope,	102.0
Head of Old No. 5 slope,	352.0
Foot of Old No. 5 slope,	191.0
Foot of New No. 5 slope,	—25.0
First lift of New No. 5 slope,	180.0
First lift of Old No. 5 slope,	272.0
Top of Rock plane,	361.0
Foot of Rock plane,	330.0
Top of No. 1 plane, Red Ash bed,	403.0
Foot of No. 1 plane, Red Ash bed,	333.0
Top of No. 2 plane, Red Ash bed,	448.0
Foot of No. 2 plane, Red Ash bed,	396.0
HOLLENBACK COLLIERY, (L. & S. R. R.)	
Head of No. 2 slope,	774.0
Foot of No. 2 slope,	554.8
Head of slope No. 1, (inside,)	—25.8
Foot of slope No. 1, (inside,)	135.8
Head of slope No. 2, (inside,)	557.5
Foot of slope No. 2, (inside,)	345.0±
Head of slope No. 3, (inside,)	689.9
First lift of slope No. 3, (inside,)	470.0
Second lift of East slope No. 3,	380.0
Top of shaft,	545.5
Foot of shaft,	—31.9
Top of air shaft,	591.5
Foot of air shaft,	266.3
Foot of plane to air shaft,	—27.0
Foot of Diamond plane to air shaft,	51.0
First lift of plane to air shaft,	29.0
Second lift of plane to air shaft,	135.4
Third lift of plane to air shaft,	213.0
DIAMOND SHAFT COLLIERY, (L. & S. R. R.)	
Top of shaft,	601.0
Foot of shaft,	228.0
Head of Old slope,	234.7
First lift of Old slope,	182.0
Second lift of Old slope,	128.0

	Feet above tide.
Third lift of Old slope,	48.0
Head of new slope,	241.4
First lift of new slope,	172.0
Second lift of new slope,	128.0
Third lift of new slope,	50.0
Fourth lift of new slope,	— 1.7
Foot of new slope,	—50.0
Head of rock plane,	229.7
Foot of rock plane,	74.7
Top Grant Street bore-hole,	656.6
Bottom Grant Street bore-hole,	93.1
RED ASH NO 1 COLLIERY, (L. & S. R. R.)	
Head of rock slope,	928.5
Foot of rock slope,	887.4
Head of No. 1 slope,	907.0
Foot of No. 1 slope,	824.0
Mouth of No. 1 drift,	929.9
Mouth of No. 2 drift,	987.0
Mouth of tunnel,	886.2
Mouth of Ross drift,	927.0
RED ASH NO. 2 COLLIERY, (L. & S. R. R.)	
Mouth of tunnel,	941.2
Mouth of Red Ash drift, No. 2,	987.0
HILLMAN VEIN COLLIERY, (L. V. R. R.)	
Top of shaft,	550.0
Hillman landing,	465.0
Bottom landing,	269.0
Top of air shaft,	546.0
Foot of air shaft,	470.0±
Head of inside slope, N. dip, Hillman bed,	470.0
Head of inside slope, S. dip, Hillman bed,	467.0
Foot of inside slope, S. dip, Hillman bed,	419.0
S. end of inside tunnel,	273.0
N. end of inside tunnel,	276.0
CONYNGHAM COLLIERY, (L. & S. R. R.)	
Top of shaft,	571.08
Foot of shaft,	178.97
Head of Young's slope,	562.9
BALTIMORE COLLIERY, (L. & S. R. R.)	
Head of Baltimore slope,	702.7
Mouth of Old Baltimore tunnel,	602.8
Head of inside slope, Baltimore tunnel,	602.8
First lift of inside slope,	545.0
Second lift of inside slope,	455.0
Third lift of inside slope,	355.0
Head of inside slope near land line, (N. dip,)	617.0
Head of inside slope near land line, (S. dip,)	617.0
Head of Baltimore shaft,	646.0

	Feet above tide.
MINERAL SPRING COLLIERY, (L. & S. R. R.)	
Head of slope,	707.4
First lift of slope,	508.8
Second lift east of slope,	554.5
Second lift west of slope,	545.2
Fourth lift of slope,	479.9
Fifth lift of slope,	418.8
Sixth lift of slope,	339.1
Foot of slope,	300.4
Head of inside slope, No. 1,	288.2
First lift of inside slope, No. 1,	257.8
Foot of inside slope, No. 1,	225.0
Head of inside slope, No. 2,	288.2
First lift of inside slope, No. 2,	204.8
Foot of inside slope, No. 2,	144.8
First lift tunnel to Cooper bed,	611.9
First lift tunnel to Ross bed,	618.3
Fifth lift tunnel to Ross bed,	414.6
Head of rock plane,	569.6
Foot of rock plane,	548.4
Bottom lift, tunnel to Ross,	303.2
LAUREL RUN COLLIERY, (L. & S. R. R.)	
Head of slope,	608.1
PINE RIDGE COLLIERY, (L. & S. R. R.)	
Head of shaft,	599.0
MILL CREEK COLLIERY, (L. & S. R. R.)	
Head of slope,	609.9
DORRANCE COLLIERY, (L. V. R. R.)	
Top of shaft,	591.6±
Foot of shaft,	12.0±
PROSPECT COLLIERY, (L. V. R. R.)	
Top of shaft,	674.5
Foot of shaft,	85.1
Top of No. 1 plane,	147.9
Foot of No. 1 plane,	99.9
Top of No. 2 plane,	175.0±
Foot of No. 2 plane,	89.7
Top of Plane, No. 3,	222.1
Foot of Plane, No. 3,	188.4
Top of Plane, No. 4,	261.7
Foot of Plane, No. 4,	222.8
Top of Plane, No. 5, (Lower Baltimore,)	224.1
Foot of Plane, No. 5, (Lower Baltimore,)	182.0±
Head of inside slope, No. 1,	84.6
Foot of inside slope, No. 1,	42.2
OAKWOOD SHAFT, (L. V. R. R.)	
Top of shaft,	678.4
Foot of shaft,	52.2
Upper landing of inside slope,	— 46.9

	Feet above tide.
First lift of inside slope,	—214.7
Foot of inside slope,	—292.1
MIDVALE COLLIERY, (L. V. R. R.)	
Head of slope,	639.2
First lift of slope,	552.7
Second lift of slope,	420.0
Tunnel foot of slope,	419.5
Tunnel to Bowkley bed, second lift, S. end,	430.0
Tunnel to Bowkley bed, first lift, S. end,	554.1
Head of Second Opening slope,	678.0
First lift of Second Opening slope,	496.7
Second lift of Second Opening slope,	424.0
Third lift of Second Opening slope,	286.7
Tunnel to Bowkley, third lift, S. end,	290.0
Tunnel to Hillman, third lift, S. end,	292.7
HILLMAN COLLIERY, (L. V. R. R.)	
Head of Hillman Bed slope, S. dip,	568.9
Foot of Hillman Bed slope, S. dip,	364.0
Mouth of Hillman Bed drift,	551.7
Head of Hillman Bed slope, N. dip,	580.7
Head of Abbott Bed slope,	540.6
Head of Rock slope,	540.1
HOLLENBACK (R. S. POOLE) COLLIERY, (L. V. R. R.)	
Head of slope south of breaker,	592.7
Head of slope east of breaker,	598.4
Head of Plank Road slope,	616.6
WYOMING COLLIERY, (L. V. R. R.)	
Head of inside plane,	376.5
Foot of inside plane,	311.7

CHAPTER VIII.

Basins and Anticlinals in the Northern Coal-field.

Introduction.

Before describing the individual anticlinals and basins, which have so far been traced by the present Survey in the western end of the Wyoming valley, it is desirable that an outline of the general geological structure of the Northern Coal-field should be given, since the geology of the Wyoming and Lackawanna valley is distinct in many of its features from that of the other anthracite basins.

In the report of the First Survey (1858) a general reference is made to the undulations found in the strata of the Northern field. Many of the conclusions there stated have been confirmed by the mining developments of the past thirty years. Prior to the time of the examinations of the First Survey, the knowledge of professional geologists and mining engineers, as to the details of the structure of the anthracite basins, was very imperfect, and although some of the suggestions then made have not been borne out by facts subsequently obtained, yet so many of them have proved correct, that theinsight which the assistant geologists of the First Survey had of the general geological structure, calls forth admiration.

The description referred to is republished here from the Final Report, and, with the slight modifications suggested in the foot notes, is as applicable to the correct understanding of the underground geological structure of the field as when it was first published.

*Undulations of the Wyoming-Lackawanna Basin.**

"There are several features connected with the undulations of the coal measures in the Wyoming and Lackawanna

*Geology of Penn'a, 1858, Vol. II, page 324.

valley, which claim attention in any general survey of the structure and mining capabilities of this basin, or in any comparison of the resources of its different sections. Some of these concern the directions of the undulations with respect to each other and to the course of the general valley which contains them, while others belong to the forms of the undulations and the law of their steepening and subsiding.

"1. The feature of widest generality connected with these anticlinal and synclinal waves, or saddles and troughs of the strata, is their remarkable approximation to parallelism throughout the entire range of the basin, irrespective of the bending course of the Main Valley and its including mountains. This constancy in the direction of the waves, though singularly close, is not absolute when those of distant sections of the valley are compared, there being a difference between the anticlinals of the vicinity of Wilkes Barre and those of the Lackawanna valley of some 6°, the former ranging about N. 67° E., while the latter observe an average course of N. 72° or 73° E.

"As a natural consequence of this approximate permanency of direction of the undulations and the curving outline of the general basin, it is only in the lower or W. end of the valley that these rolls of the strata are parallel, or even nearly so, within the main course of the valley. There the chief groups among the anticlinals approach to a coincidence in direction with the mountain forming the S. side of the basin. Advancing N. E. to the Wilkes Barre and Pittston districts, this parallelism with the mountain border is more and more departed from, and with its progressive deflection to the N., along the S. E. side of the Lackawanna Valley, the obliquity of the undulations to the line of the basin and its barriers grows conspicuously greater. From the vicinity of Wilkes Barre, and probably from further W. the whole way to Carbondale, these anticlinals come forth in succession from the mountain sides of the valley at larger and larger angles as we advance towards the N. E., the anticlinal waves, broad and flat on the slope of the mountains, pointing down obliquely W. into the valley,

and contracting and growing steeper; while the synclinal troughs between them rise out of the central bed of the basin, flattening and shoaling up to the E., to disappear at higher levels on the same mountain sides. This arrangement is discernible in the undulations of both sides of the basin, but those of the S. E. side being more numerous, of steeper flexure, and less obscured by diluvial drift, the feature is there more conspicuous. Each of the two mountain barriers of the valley, with its set of anticlinal spurs passing off from it at successively increasing angles, may be likened to a curving fish-back, one concave, the other convex, sending out its spines or rays at increasing obliquities, but in mutual parallelism with one another.

"2. A further general fact connected with these undulations of the coal measures, interesting for its geological bearings and not less so for its practical consequences, is the curious declining gradation observable in the sharpness of the successive undulations as we proceed from S. W. to N. E. along the basin. Not only does each anticlinal of the S. E. side of the valley grow gentler or flatter in its dips as it slowly rises to the E., but the successive ones are fainter and fainter at the same proportionate sections of their length as we cross them obliquely in going towards the N. E. Those of all the lower or W. end of the valley, from Beech Grove* to Nanticoke, show inclinations as high as 45°; those between Nanticoke and Wilkes Barre display dips exceeding 30°†; and those between Wilkes Barre and Pittston, dips averaging 20° or 25°; while, following the Lackawanna division of the basin, we have no longer anything approaching this last steepness of flexure—except just near the ends of the saddles—but rather a low broad waving of the rocks, growing feebler and feebler as we advance, until, passing Scranton into the district between it and Archibald, regular undulations become almost imperceptible and are lost‡ in the very gradual dips into the mid-

*Mocanaqua.—(C. A. A.)

† Except at the Stanton, Franklin, and Henry and Wyoming overturns, and at the Pa. C. Co. fault, where the strata have vertical and overturned dips.—(C. A. A.)

‡ Except Priceville and Peckville anticlinal.—(C. A. A.)

dle of the general trough from the two borders of the valley. Accompanying this progressive smoothing-out of the waves or corrugations of the strata from the S. W. towards the N. E. end of the whole basin, there is a like gradual transition of declension in its external features, from sharp and narrow-crested ridges and deep hollows to rounder and gentler spurs and valleys, and along the Lackawanna to wide-topped summits, bluffs, and open denuded plains.

"3. Other points of general structure appertaining to the interior undulations of the main basin have reference to the prevailing *form* of the anticlinals and their troughs. A main feature in the individual waves is a progressive increase of flexure, or a steepening of the dips on both sides of the anticlinals as they advance from the mountain sides, where they originate, out into the central tracts of the valley to near their terminations, which are, therefore, comparatively abrupt. Remarkably clear exemplifications of this structure present themselves to any close observer of the anticlinals between Wilkes Barre and the Lackawanna. If these be carefully traced from the E. down to this district, they will be seen to grow steadily sharper and sharper in their dips, until they approach, in their oblique course, to the banks of the Susquehanna, in the neighborhood of which they nearly all subside by bluntly rounding off. In proof of this abrupt cessation we have only to remark the contrast between the general steepness of these undulations where they are crossed slantingly by the old stage road, or even by the plank road, and the extreme gentleness and absolute disappearance of many at the canal, and especially at the shore of the river. The very position in the valley which the river has taken between the mouth of the Lackawanna and Wilkes Barre is an evidence of the sudden dying out of this southern system of anticlinals. It would seem as if the waters, in scooping the lower valley or plain within which the Susquehanna flows, had been unable to pass the succession of barriers presented to them by these ridges in the strata, and were forced to recoil by the N. flanks and bold ends which the saddles protruded against them, swinging off in their rebound to follow the deflecting

course of the waves of the strata towards the outlet of the drainage of the valley, the wide notch in the northern mountain-barrier at Nanticoke.

"The N. or N. W. side of the valley appears to have its own set of anticlinals or saddles, as already intimated. Whether these observe the same law in their oblique descent into the valley from the W. of a progressive increase of dip on both their flanks, I am not prepared at present to maintain. as the structure of this portion of the valley is largely disguised by surface drift, and as the points of many of the spurs or saddles are hid by the deep diluvium of the Wyoming and Lackawanna flats. All analogy, and every theoretical consideration of the origin of this curious feature in the anticlinals, would indicate, however, that the same steepening towards their terminations belongs to these waves which characterizes those coming from the opposite mountain lying E. Whether any of the flexures of the upper strata cross the basin entirely, passing W. from the Southern mountain to coincide with undulations proceeding E. from the Northern, cannot be at present known; but the general cessation of both sets towards the middle of the basin is a strong intimation of the improbability of such a condition.

"4. Besides the long, parallel, tapering anticlinal waves coming very acutely off from the mountain-borders of the basin, there are numerous shorter and narrower ones having the form of oval keels or saddles, which do not run into the mountains, but lie more or less insulated. Undulations of this class are more frequent in the central tracts of the valley than towards the sides, and their relative proportion to those of the longer form seems to increase steadily towards the upper or N. E. end, becoming between Scranton and Carbondale rather the prevailing type. In the uppermost parts of the Lackawanna basin we may indeed generally describe the flexures of the strata less as continuous waves or ridges than as successions of these elongated elliptical swells, some of them bulging into considerable steepness, but the chief part of them low and gentle waves, often too obscure to be detected externally in the topo-

graphy, or in the dipping rocks, yet obvious in the mining of the coal, over which the feeblest undulations exert an almost tyrannic control as regards the direction of the levels and gangways within the mines. It is a consideration of this important connection between the forms of the crust waves and the whole economy of mining in our undulating coal-fields that induces me, in this place, to dwell so minutely on the several shapes which these assume.

"5. There is still a lesser class of undulations in the coal rocks which the progress of mining in the region is constantly bringing to light, and which demands some mention here. These are the small, irregular, subordinate rolls, or short and narrow, but not always flattish wavings of the strata, on the flanks of the principal anticlinals. In some districts of the anthracite basins these secondary flexures, whether on the backs or sides of the main saddles, or in the troughs between them, are, for the most part, parallel with the principal undulations which support them; but in the Wyoming and Lackawanna coal-field, and other regions of oblique anticlinals, they are themselves acutely oblique to the axes of the great waves which sustain them. Their arrangement is somewhat analagous to that of the small feathers or plumelets on the side of a bird's wing. While the whole wing diverges and tapers from the body of the bird—the mountain boundary of the basin—these lateral lesser plumes diverge and taper in their turn from the main direction or axis of the wing. Wherever this structure prevails in its fullest symmetry the mine levels or gangways, when extensive, will, in winding in and out on the sides, or at the foot of a chief anticlinal ridge, have that variety of the scallop form which we may call oblique, the convex loops all pointing in one direction, that, namely, towards which the main anticlinal is itself subsiding. The secondary rolls are numerous in the great mine of the Baltimore Company near Wilkes Barre.

"6. Viewing the undulations of the Wyoming and Lackawanna coal-field transversely or in profile, they exhibit, in the main, the same feature of a preponderating steepness of dip on their north-western sides which characterizes the

chief part of the secondary flexures of the Pottsville basin; but inasmuch as all the inclinations of the rocks of this Northern district are far gentler than those of the Southern coal-field, in the same proportion is the inequality less in the slopes of the opposite sides of the anticlinals, until, in the Lackawanna Valley and other gently undulated districts, the difference in an average of several waves is almost imperceptible. The general trough-like structure of the valley in these sections disputing its influence on the inclination of the strata with the local flexures, the undulations of the S. E. side of the basin show their steepest dips to the N. W., or towards the bed of the valley, while those of the N. W. side exhibit theirs on their S. E. flanks, or towards the same controlling synclinal line. In the W. end of the Wyoming valley, the undulations being there sharper, the general law of inequality in the slant of the sides of the waves is much more conspicuous than in the Lackawanna valley, where all the flexures are flatter, and where local swells have relatively greater power to disguise the existence of any general law of form in the undulations."

Description of the Basins and Anticlinals of the Wyoming Valley.

The positions of the axes of all the principal anticlinals and basins which it was possible to locate in that portion of the Wyoming valley embraced by mine sheets, Nos. III to VIII, inclusive, have been indicated by blue lines on the published sheets. (See Atlas Northern Anthracite Field, Part I.) Many other anticlinals will be found to exist in the Wyoming basin, whose positions are either not indicated on the mine sheets or have not been determined.

Where the general dip of the coal-beds is slight, many local rolls exist in them, which are very important, as affecting the plan of the mine workings and the system of mine drainage. A rise of only a few feet within a considerable distance will have an important bearing upon both. Such rolls can not, as a rule, be discovered by surface surveys, but by actual exploitation of the coal-beds.

In this connection may be mentioned the anticlinal found about midway down the slope, driven south-east from the foot of the "Harry E" shaft, and shown in section No. 24, cross-section sheet, No. IV. The position of this anticlinal is not indicated on the accompanying mine sheet, since the dips on either side, while very important to the miners, are so slight that at the time this sheet was constructed it was hardly possible to assert with positiveness that this anticlinal was one continuous flexure from the "Harry E" slope north-west into the mine workings of the Black Diamond colliery, 1200 feet to the south-west, although it is probably represented by the slight rise in the Bennett bed immediately to the south-east of the Black Diamond shaft.*

Many other anticlinals may be instanced as occurring in the Wyoming basin, but whose positions are not shown on the map, and to which no special mention is made in this report. They are local features of great importance to the individual mine operators, but would not be generally interesting in a description of the prominent structural features of the valley.

The system which has been adopted by the present Survey of designating anticlinals in the coal measures is very nearly the same as that which was originally used by the first State Survey.

The true classical method of naming flexures existing in sedimentary rocks is to apply the name anticlinal to those strata which dip in opposite directions from a common ridge or axis, like the roof of a house; and to apply the word synclinal to those strata which dip in opposite directions inward, like the leaves of an open book. In the case of the maps and reports relating to the Anthracite Survey, I have diverged from this general plan, and have designated the latter by the word basin, rather than by the word synclinal. This has been done for the reason that the word basin is more generally applied to the latter flexure by

*During the past year the mine workings of the Black Diamond colliery have been considerably extended, and the new development, when carefully studied, will doubtless determine this question.

practical men, and has been universally assigned, with local names prefixed to well recognized synclinals.

Maltby Anticlinal.

The Maltby anticlinal passes immediately in front of the Maltby tunnel, and has a course south 61½° west, to a small tunnel driven north-west from the Bennett bed, in the Forty-Fort Colliery. The colliery workings encountered it on either side of the anticlinal, after leaving the tunnel again, and also in the center of the tunnel itself.

Plains-Yatesville Anticlinal.

Yatesville is located on Mine Sheet No. X and Plains in the north-eastern corner of Mine Sheet No. VIII. The position of the anticlinal, which takes its name from these two villages, would seem to be indicated by a continuous straight line between them.* Its location, east of Plains, is indicated by the dip of the outcropping rocks, and west of Plains by the mine workings of the Enterprise colliery. The outline of the mine workings at this colliery, shown on Mine Sheet No. VII, clearly indicate the position of the anticlinal, although the intensity of the dip on either side of the axis is not shown. No levels had been run through the gangways of this colliery up to the time that the Survey map was constructed, and in consequence the structure of the coal-bed is not shown by contour curve lines drawn along the floor of the bed, as has been done in most of the other colliery workings on the Wyoming Mine sheets.

Although the mine workings, which will ultimately be driven in coal-beds between Plains and Yatesville, will undoubtedly show a roll in the coal-beds in close proximity to the axial line of these anticlinals, shown on Mine Sheet No. VII, yet it is possible that the anticlinal may not be one continuous flexure between these two villages.

---

*See Mine Sheet No. 8, Rothwell's topographical map, and the skeleton map of the Wyoming basin, (scale 1 mile to 1 inch.)

The general tendency of the anticlinals, in the anthracite coal measures, is to die out in comparatively short distances and to be replaced by other anticlinals which gradually develop alongside of the first, which latter gradually dies out. This general feature is amply shown by the mine and cross-section sheets, which have already been published by the Survey, relating not only to the Northern coal-field, but on those relating to the Eastern Middle, Western Middle, and Southern coal-fields.

Where such a structure exists, the gangways which are "*driven*" to work the coal-beds will not be straight, but their general direction may be defined by a straight line, broken at points by local curves, which will make the gangway assume the form of the letter "S" where it goes around the ends of both the dying and developing anticlinals. This remark applies not only to the Plains-Yatesville anticlinal, but to all other anticlinals which are shown on the Survey sheets, as being approximately straight, and whose positions have been hypothetically deduced from connected observations of surface outcrops and not from actual mining developments.

Henry Anticlinal.

This anticlinal is first seen at an elevation of about 300 feet above tide in the Baltimore bed of the Henry colliery, and has only been traced as far as the western limits of the mine workings of the same colliery. The dip of the Baltimore bed from the axis of the anticlinal, on either side, varies considerably at different points along the anticlinal, so that the workings are very much more modified at one point than at another.

Henry Basin.

This basin is closely allied to the Henry Anticlinal, and runs nearly parallel to it, at the eastern end. The axial lines are about 200 feet apart, immediately north of the Henry shaft about 400 feet apart, and at their western limit about 300 feet apart. The dips on either side of the basin, and towards its center, have a more decided influ-

ence upon the position of the mine workings than the dips on either side of the anticlinal.

Henry and Wyoming Fault.

The occurrence of a true break or slip fault in the anthracite coal-beds is comparatively rare. Where they have been found they are usually the result of an overturned anticlinal. Such a fault was passed through by the Henry shaft. The bottom of the shaft is in the Bennett or Lower Baltimore bed, and between this point and where the shaft passed through the Upper Baltimore bed, the lower bed was found on the upper side of the fault. This fault has also been proven by one of the underground slopes at the Wyoming Colliery.

There are many interesting structural features connected with the occurrence of this fault, and concerning which the Survey is at present collecting information, upon which will be based a special map and description of the fault for subsequent publication. As nearly as could be determined, from the examination which has so far been made, the position of this fault is as indicated on Mine Sheet No. VII, and the local structure of the fault, at the Henry air shaft, is shown on section No. 28, Cross-section sheet No. IV.

Wyoming Shaft Anticlinal.

The position of this anticlinal is clearly defined by the mine workings from the Henry and Wyoming Colliery shafts where the anticlinal was encountered in the mine workings in the Baltimore bed, directly to the south of Henry plane, No. 7. Its crest slopes to the west about 1 foot in every 7 feet. To the south of the Henry air-shaft its crest sinks more rapidly. This feature is shown by the contour curve lines drawn along the floor of the Bennett bed in the Henry mine workings. The western portion of the anticlinal in the Wyoming workings is much sharper, and the dip steeper on either side, than in the Henry workings, and the anticlinal will be found to die probably north of the Susquehanna river.

Mill Creek Slope Basin.

The general features of the structure of this basin are probably more regular than those of any one basin within the area across which the structural lines just referred to pass. The basin is first boldly defined by the gangways driven in the Bennett and Cooper beds from the Mill Creek slope and Wyoming shaft. The general structure of this basin east of the Susquehanna river is suggestive of the conclusion that the basin probably becomes more prominent west of the river.

Mill Creek Slope Anticlinal.

The direction of the crest of this anticlinal would seem to make a rather sharp angle on Mine Sheet, No. VIII, about 1000 feet north of the Mill Creek breaker. Immediately east of this point there are no mine workings from which to locate the anticlinal. The geological facts to be had from surface examinations would lead to the conclusion that the anticlinal is very nearly parallel to the axis of the Wyoming shaft anticlinal west of this point. The axial line of the anticlinal bends to the south, and its position is clearly defined by the mine workings of the Mill Creek slope, Wyoming shaft, Hollenback (R. S. Poole) colliery, and the gangways which form a part of the mine workings of the Prospect colliery; passing under the Susquehanna River bed, and around the anticlinal, nearly 1200 feet west of the river bank. In this locality the crest of the anticlinal sinks about 150 feet in 800 feet, and the dips on either side are sharper than elsewhere along the crest.

Prospect Shaft Basin.

This basin is a local feature, which has been developed more particularly by the mine workings of the Hillman and Prospect collieries. It is characterized by the fact that just north of the Prospect shaft it shows very distinctly in the Upper Baltimore bed, immediately under the point where the Midvale slope is driven into the Hillman bed, and where no indication of the existence of such a basin is observed. In fact, the Midvale slope is apparently driven

on the south side of an anticlinal which exists in the Hillman bed immediately over the basin which exists in the Baltimore bed.

This feature is illustrated by Section, No. 34, on Cross-Section Sheet, No. IV, and is referred to as a caution to mining engineers and geologists in deducing conclusions as to the geological structure which may exist in one coal-bed from the geological structure which may be absolutely determined by mine workings in an overlying or underlying coal-bed.

Prospect Shaft Anticlinal.

The line marking the crest of this anticlinal conforms almost absolutely to the axial line of the Prospect basin. The most eastern location of this anticlinal which has been determined is in the Baltimore workings of the Pine Ridge shaft, through which it passes, at a point about 600 feet north of the shaft, and continues nearly due west to the Hillman colliery breaker, under the southern corner of which it passes; then deflects toward the south-west to the Prospect shaft, having cut the Baltimore beds included in the crest of the anticlinal. Both the Prospect Shaft anticlinal and basin may be considered local features in comparison with the Mill Creek anticlinal and basin.

Cemetery Basin.

This basin has been encountered in the Baltimore workings from the Pine Ridge shaft, through which the center of the basin has a general south-west direction; but, on leaving these workings, the center of the basin deflects toward the north; passes through the workings of the Abbott bed from the Hillman slope; crosses the railroad twice in the vicinity of a drift driven in the New bed, and over the southern end of the Rope-way slope from the Oakwood shaft; crosses Chestnut street to Mill Creek street near its intersection with Franklin street, and then passes through the Hollenback Cemetery, where its position is lost in the Susquehanna river.

The position of this anticlinal has been determined alone from the dip of the outcropping rocks, no mine workings having ever been driven across its axis. Its line crosses Franklin street near the intersection of Elk and Pine streets, runs along parallel to Pine street, and crosses River street between Linden and Maple streets, through both the Hollenback and Public Cemeteries, and is lost along the river bank north of the Dorrance shaft. Its dips are best seen in the L. V. R. R. cut, on the Main Street hill west of Mill creek, and in the Dorrance air-shaft.

Gas Works Basin.

The position of this basin has been determined alone from surface observations. It crosses Main street between Conyngham and Courtright avenues, passes to the north of Bowman's hill, and crosses River street a short distance east of North street, and south-west to the gas works, where it is plainly developed by opposite dips on the river bank. The Conyngham shaft is on the south side of this basin.

Conyngham Anticlinal.

The first evidence which has been found of the existence of this anticlinal is in the vicinity and to the east of Laurel Run slope, and its position is clearly defined by the Laurel Run, Baltimore, Conyngham, Hillman Vein, and Hollenback mine workings. The elevation of the outcrop, at the mouth of Laurel Run slope, which is driven in the bottom member of the Baltimore bed, is 608 feet above tide. The crest of the anticlinal from this point falls rapidly for a distance of about seven eighths of a mile (4550 feet), to the bottom of the Baltimore slope, where the elevation of the crest of the anticlinal is about 255 feet above tide. From this point south-west about half a mile (2700 feet), the crest of the anticlinal falls 50 feet, south-west from this point to a point under Canal street, midway between North and Beaumont streets, a distance of about 3200 feet, the crest falls a little more than 200 feet to an elevation slightly below tide

level. The steepest dips on either side are, without doubt, located between the foot of Baltimore slope and a plane driven southeast from the Conyngham shaft.

Conyngham Shaft Basin.

The direction of the center of this basin conforms very nearly to the direction of the Conyngham anticlinal, and is co-extensive with it from Laurel Run slope to the Hillman Vein shaft. The distance between the two axial lines varies from 200 to 400 feet. The subsidence of the bottom of the basin is in a general way coincident with the crest of the anticlinal.

Hollenback Air-shaft Anticlinal.

The location of the crest of this anticlinal is readily shown by the mine workings of the Baltimore, Diamond, and Hollenback collieries, and from the dips of the outcropping rocks between the Mineral Spring colliery and the South Wilkes Barre shaft workings. The elevation of the crest of the anticlinal in the Baltimore bed at the Baltimore slope is about 675 feet above tide. If the anticlinal in this bed falls progressively towards the south-west until at a point near the intersection of Northampton and Wells streets south-east of the old Lehigh Valley depot, the elevation of the crest of the anticlinal in the same bed is tide level. South-west of this point there are no mine workings in the vicinity of the anticlinal, and its position has been determined by surface outcrops.

Baltimore Shaft Basin.

The direction of the Baltimore shaft basin conforms very nearly to the Hollenback air shaft anticlinal, and is boldly marked by the Baltimore and Hollenback mine workings in the Baltimore bed. About 300 feet north of the Baltimore shaft, the elevation of the top of which is 640 feet above tide—the elevation of the bottom of this basin is 400 feet above tide. The elevation of the bottom of the basin under Coal street, about midway between Grant and Sherman streets, is at tide, and in the vicinity of the Grant Street

bottom of the basin at this latter point about 750 feet. (See Section No. 31, Cross-Section Sheet No. V.)

Baltimore-Stanton Anticlinal.

The position of the crest of this anticlinal in the Baltimore bed is distinctly marked by the mine workings of the Baltimore tunnel, Empire, and Diamond colliery workings, and by the dip of the outcropping rocks in the vicinity of Laurel Run. The elevation of the crest of the anticlinal, about 100 feet south of the face of the Baltimore tunnel, is 630 feet above tide, and it dips rapidly toward the southwest, where the anticlinal crosses Northampton street about a quarter of a mile north-west of the Empire office of the Lehigh & Wilkes Barre Coal Company. The elevation of the crest in the Baltimore bed is 250 feet above tide. This anticlinal is probably identical with the Stanton Air-Shaft anticlinal, the position and structure of which are clearly shown on Mine Sheet No. VI.

Empire Basin.

This basin is one of the most striking and extensive in the Northern Coal-field, the features of which are clearly shown by the workings of the Empire colliery of the Lehigh & Wilkes Barre Coal Company. The dips of this basin are so clearly shown by mine workings and underground contour curves on Mine Sheet No. VIII, and Sections Nos. 32 and 33 on Cross-Section Sheet No. V, that any further explanation is not needed here. Between the point immediately north of the Empire shaft and the Stanton shaft, the exact position of the center of this basin is not fully determined by the mine workings as shown by Mine Sheets Nos. VI and VIII.

Stanton Anticlinal.

This is a local anticlinal which is developed in the Baltimore Coal-bed between the Old Kidder breaker and the Empire shaft breaker.

Stanton Basin.

This basin in the Baltimore bed extends from a point south of the Old Kidder breaker, immediately under the south end of the Empire shaft breaker, and thence to a point under the Stanton shaft breaker. This basin and the Empire basin in the vicinity of the Stanton shaft are closely connected with the Stanton overturn which has been clearly defined in the vicinity of Stanton, No. 7, shaft, both by the shaft and a tunnel driven from the north-dipping Baltimore bed in the Stanton basin to the north-dip of the same bed in the Empire basin. It is proposed to make a special study and map of this overturn for future publication.

Franklin Slope Anticlinal.

This flexure is clearly defined by the mine workings in the Red Ash bed at Empire, No. 2, slope and the mine workings in the Baltimore bed at the Franklin slope. Immediately to the south of the western end of this anticlinal, in the south-eastern portion of the town of Ashley, the Baltimore bed is overturned on itself, forming the Franklin overturn. A special survey and map of this overturn is to be made in conjunction with similar examinations of the Stanton and Henry overturn, and also of the Reynolds fault anticlinal, the position of which is shown on Mine Sheet No. V. From the Empire slope, No. 3, a small basin and anticlinal exist of only local extent.

Newtown Basin.

The existence of this basin in the Baltimore bed is first shown by the mine workings from Empire slope, No. 3, the elevation of the crest of which, at the outcrop, is about 725 feet above tide. This basin sinks rapidly to a point about three eighths of a mile east of Nanticoke Junction, at Ashley, where the elevation of the crest in the Baltimore bed is 250 feet. From this point the center of the basin passes under Ashley, No. 6, breaker, through the center of the village of Newtown, and its last development in the mine workings is found in those of the Kidney bed, at the Sugar Notch colliery.

Ashley Shops Anticlinal.

This anticlinal is developed by the Ashley colliery workings in the Baltimore bed and the Sugar Notch workings in the Kidney bed, also by the dip of outcropping rocks along its extent. Its axis is beautifully exposed in the railroad cut at the Ashley shops, from which the anticlinal has been named.

Petty's Pond Basin.

This basin is defined by the mine workings in the Baltimore bed from the Stanton shaft and by surface exposures. Petty's pond is directly over the center of the basin, as nearly as can be determined, hence the name.

Stanton Bore-Hole Anticlinal.

The position of this flexure is determined by the Stanton bore-hole and tunnel driven through the anticlinal connecting the Baltimore bed workings on either side of it, and by surface exposures along the crest throughout the north-western part of the village of Ashley.

Ashley Cemetery Anticlinal.

The axis of this anticlinal was located from surface exposures in the vicinity of Ashley cemetery and at the junction of what is known as the Middle road with a road running south towards Sugar Notch. A great many exposures can be found along the continuous extent of this anticlinal as shown by Mine Sheet No. VI. No mining developments have been made in its vicinity.

Hanover Green Anticlinals.

The north, middle, and south Hanover Green anticlinals occur immediately south of where Buttonwood creek empties into the Susquehanna river. These anticlinals are distinctly marked by the dip of the outcropping rocks, and, although their extent is apparently limited, they will no doubt have a very important bearing upon the economical mining of coal in their vicinity.

Butzbach's-Buttonwood Anticlinal.

This flexure exists from the Old Buttonwood shaft, which was sunk almost immediately on the crest of the anticlinal to a point on the Susquehanna river immediately below Butzbach's Landing, near the mouth of Buttonwood creek.

Behee's Pond Anticlinal.

Numerous exposures with well defined dips exist along the crest of this anticlinal, as defined on Mine Sheets, Nos. VI, IV, and III, and at several points the rocks are exposed immediately over the center of the anticlinal with visible dips on either side. This anticlinal has been traced from a point about three quarters of a mile north of the village of Sugar Notch, south of west of the southern limits of the town of Nanticoke, and is probably identical with the anticlinal encountered by the extreme southwestern workings in the Mills bed from Susquehanna shaft, No. 1, west of Nanticoke.

Hanover "Hogback."

This is one of the most prominent geological features in the Wyoming Valley, and its position is marked by the boldest topography which is found between the mountain limits of this part of the valley. The bold outcrops of sandstone and conglomerate which occur along it have been sometimes locally mistaken for outcrops of the Pottsville Conglomerate, No. XII, and, in consequence, it has been naturally inferred that no coal exists underneath the surface in this part. This is a great mistake, since the sandstone and conglomerate which outcrop along the Hanover "Hogback" is above the Kidney coal-bed in the geological column, and there is no geological reason why all the coal-beds which are mined between Ashley, Plymouth, and Nanticoke, occurring

passed through and defined the thickness and position of all these coal beds. The record of this hole is not in possession of the Survey.

The line of this "Hogback" has been traced from a point half a mile north of the village of Sugar Notch to a point immediately north of the junction of the Nanticoke and Wanamie branches of the Lehigh and Susquehanna R. R., and its position has been carefully mapped on the mine sheets already referred to.

Sugar Notch, No. 10, Breaker Anticlinal.

The axis of this anticlinal is clearly defined by the dip of the outcropping strata, and from cross-sections constructed across the mine workings of Sugar Notch collieries, Nos. 9 and 10.

Sugar Notch Tunnel Anticlinal.

This anticlinal has been encountered in the mine workings of Sugar Notch No. 9, colliery driven in the Ross coal-bed. It does not probably extend much beyond the Maffet colliery, as shown on Mine Sheet, No. VI.

Bennett's Creek Anticlinal.

This anticlinal lies between the village of Sugar Notch and Warrior Run colliery, and its axis was located by continuous dips. West of Warrior Run colliery another anticlinal is shown by outcrops located along Warrior run near the junction of its head forks. This is probably the continuation to the south-west of the Bennett's Creek anticlinal. No outcrops can be found between the two anticlinals, as shown on the Mine Sheet, No. IV, so that each has been described by individual names.

Mocanaqua-Warrior Run Anticlinal.

The position of the eastern end of this anticlinal is shown by steep dips at Plumbtown, and its position as indicated on Mine Sheets, Nos. III and IV, has been determined by the dip of outcropping rocks almost along its entire length.

Nowhere on Mine Sheet, No. IV, has any mining been done on this anticlinal, but on Mine Sheet, No. III, at Wanamie colliery, the bed which is locally known as the Baltimore bed, has been mined in the vicinity of the anticlinal.

Wanamie Slope, No. 18, Anticlinal and Basins.

These flexures have been clearly defined by the mine workings in the Wanamie-Baltimore bed at Wanamie colliery, No. 18, Lehigh and Wilkes Barre Coal Company. The position and local features of both the anticlinal and basins are clearly indicated by the contour lines drawn along the floor of the Baltimore bed on Mine Sheet, No. III. The north basin commences immediately at the breaker, and is exclusively developed to the south-west of it. The basin falls to the south-west along its axis 300 feet in 1600 feet, with an apparent steeper dip to the south-east side of the basin than on the north side. The south basin is really a local roll in the south side of what I have described as the north basin, and is first proven at the western end by the mine workings at a point 500 feet west of plane, No. 3. From this point the basin continues north-east to the extreme eastern limit of the Wanamie workings toward the Alden colliery. The Wanamie anticlinal runs between the two basins. It commences at the west with the south basin, and is continuous with it towards the east. An unfortunate typographical error exists on Mine Sheet, No. III, where the axes of these two basins are shown. The axis of the north basin south-west of the breaker is made continuous with the axis of the anticlinal to the north-east of the breaker. The error is easily understood by a study of the contour curve lines drawn on the floor of the Baltimore bed, and from which the true position of the axial lines can be located.

Newport Centre Anticlinals.

The existence of anticlinal No. 5, was based largely upon the dip of an outcrop in the wagon road between Newport Centre and Wanamie. Mr. Hill reports that he has failed

clinal.

The positions of the anticlinals Nos. 3 and 4, are clearly defined by numerous outcrops in their vicinity. The anticlinals Nos. 1 and 2, pass through Newport Centre for a distance of about a mile. East of Newport Centre the axial lines are nearly parallel to one another, and apparently not more than 300 feet apart at any point. It has been questioned whether two distinct anticlinals exist here, but so many dips have been measured and located that there seems to be very little doubt but that there are two distinct anticlinals.

Newport Creek Anticlinals Nos. 1, 2, and 3.

The location of these anticlinals has been determined by the dip of numerous outcropping strata immediately to the south-west of the Buck Mountain and Ross bed workings of the Susquehanna Coal Company, south of the river. The eastern ends of these anticlinals are clearly defined by the Buck Mountain mine workings. The lines of the axes of the anticlinals are nearly parallel to one another.

Honey Pot Tunnel Anticlinal.

The position of this anticlinal is boldly marked by the Susquehanna Coal Company's mine workings in the Buck Mountain bed, on both sides of the Susquehanna river at Nanticoke, and by the dip of the outcropping rocks. It

Reynolds Fault Anticlinal.

This anticlinal has been encountered in the mine workings at Reynolds, Nottingham, Gaylord, Dodson, and Lance collieries in the vicinity of and to the west of Plymouth on Mine Sheet No. V. The prominent crest of this anticlinal is shown by the contour curve lines drawn along the floor of the Bennett bed at Plymouth and those drawn along the floor of the Red Ash bed in the Nottingham and Reynolds colliery workings, also by Sections Nos. 11, 12, 13, 14, and 15 on Cross-Section Sheet No. III. This anticlinal has had a very important influence upon the mining of coal, particularly where it is overturned and apparently faulted in the Reynolds and Nottingham colliery workings. Special reference will be made to this part of the anticlinal, in conjunction with the description of the other overturned anticlinals which have already been referred to, and which are located within the area covered by the mine sheets in the Northern Anthracite Atlas, Part I.

CHAPTER IX.

Description of the Columnar Structure of the Coal Measures and Coal-beds contained in that portion of the Northern Coal-field covered by Geological and Mine Sheets, Nos. III to VIII, inclusive.

On Columnar Section Sheets Nos. I, II, III, and IV, (Plates Nos. 10, 11, 12, and 13 respectively, "Atlas Northern Anthracite Field, Part I,") there are contained sections of the coal measures and coal-beds in the Wyoming field, from Mill Creek on the east to Wanamie and Nanticoke on the west, and within the area embraced by Mine Sheets Nos. III to VIII, inclusive. These sections have been constructed from measurements made in shafts, in tunnels, and from the records of diamond and rope drill bore-holes. Where the shafts, tunnels, and bore-holes have penetrated the strata perpendicular to their bedding, the measurements obtained represent the true thicknesses of the strata; where however they have penetrated the strata obliquely to the bed planes, the measurements obtained are in excess of the true thicknesses of the strata.

The thickness of a sedimentary bed is always understood to be the distance from the bottom to the top of the bed, measured along a straight line perpendicular to the plane of either face of the bed.

The thicknesses of the strata, in the sections on the sheets referred to, are their true thicknesses, as thus defined, so that all measurements, which are taken obliquely to the bedding, have been reduced to perpendicular thicknesses. In order to permit of a comparative geological study of the prominent features of columnar sections it is absolutely necessary to publish them in this way. Difficulty is however oftentimes experienced in making a ready comparison of the separate parts of a section with the individual strata on the ground; for instance, the top of the Balti-

more bed in the Conyngham shaft was encountered at a depth of 706′ 7″, or 629′ 5″ below the bottom of the K coal-bed, which is the first bed cut by the shaft; the bottom of the K bed in the shaft being 77′ 2″ below the top of the shaft. The actual thickness, however, of the strata included between these two coal-beds is not 629′ 5″ the distance between them in the shaft, but only 553′ 5″.

From this illustration, it is readily perceived, that if any mining engineer should have in his possession the columnar section of the Conyngham shaft alone, as reduced and published on Columnar Section Sheet No. I, it would be impossible for him to descend in the shaft and to measure down to any particular stratum which he might wish to examine.

To accomplish his end it would be necessary for him to accurately measure the degree of dip of the strata in the shaft, and from the true thicknesses of the strata given on the Survey sheet compute the oblique thickness of the strata in the shaft. In order to prevent such an embarrassing occurrence, and to make the results of the Survey of the greatest practical utility, it is proposed to publish in a special volume of Anthracite Coal-field sections, the original measurements of sections made in tunnels and shafts; also the original records of bore-holes from which the reductions for dip were made by the Survey.*

In order to convey to the reader in this place an idea of the succession of the coal-beds within the Northern Coal-field area, particularly spoken of in this report, there are given below the detail records of selected sections, which illustrate the thickness and character of the coal measures and the thickness and succession of the coal-beds contained within the limits of each one of the six Northern Coal-field Geological and Mine Sheets already described. These sections have been arranged in tabular form. The measurements under the column headed "*Thicknesses measured*

there is no dip to the strata in shafts and drill-holes, as in the case of the Hanover diamond drill bore-hole, the vertical and perpendicular thicknesses are necessarily identical. In cases where the strata have a dip of 90°, the thicknesses measured in tunnels would, of course, be the true thicknesses of the strata perpendicular to the bedding. Such a case does not, however, occur in the Northern Coal-field.

Columnar Sections to Illustrate the Coal Measures on Geological and Mine Sheet No. III.

Section of No. 1 Shaft from Surface to a depth of 566′ 1″. Susquehanna Coal Co.

(Reported by Susquehanna Coal Co.)

No. of strata.	*Description.*	*Thicknesses measured vertically.*	*Thicknesses perpendicular to dip.*
1.	Surface, ...	17′ 0″ to 17′ 0″	17′ 0″ to 17′ 0″
2.	Shelly sandstone, Dip 6° S., ...	3′ 6″ to 20′ 6″	3′ 6″ to 20′ 6″
[illegible]	[illegible]	[illegible]	[illegible]

No. of strata.	Description.	Thicknesses measured horizontally.	Thicknesses perpendicular to dip.
21.	ORCHARD, SLOPE No. 4, OR H BED, .	10′ 2″ to 298′ 1″	10′ 1″ to 296′ 4′
22.	Slate and slaty sandstone, ...	24′ 0″ to 322′ 1″	23′ 10″ to 320′ 2″
23.	COAL, ...	2″ to 322′ 3″	2″ to 320′ 4″
24.	Soft slaty sandstone,	10′ 0″ to 332′ 2″	9′ 11″ to 330′ 3″
25.	Firm sandstone, . .	12′ 0″ to 344′ 8″	11′ 11″ to 342′ 2″
26.	Slate and sandstone,	22′ 1″ to 366′ 4″	22′ 0″ to 364′ 2″
27.	Fire-clay, ...	4′ 6″ to 370′ 7″	4′ 6″ to 368′ 8″
28.	HILLMAN, SLOPE No. 2, OR G BED, . .	8′ 0″ to 378′ 10″	7′ 11″ to 376′ 7″
29.	Fire-clay and slate, .	2′ 0″ to 380′ 10″	2′ 0″ to 378′ 7″
30.	Firm micaceous sandstone, ...	30′ 0″ to 410′ 10″	29′ 10″ to 408′ 5″
31.	Firm slate, ...	15′ 0″ to 425′ 10″	14′ 11″ to 423′ 4″
32.	COAL and bone, . .	2′ 6″ to 428′ 4″	2′ 6′ to 425′ 10″
33.	Slate, ...	3′ 6″ to 431′ 10″	3′ 6″ to 429′ 4″
34.	Sandstone, ...	10′ 0″ to 441′ 10″	9′ 11″ to 439′ 3″
35.	LANCE OR 4-FT. BED, (coal, bone, and slate.)	5′ 0″ to 446′ 10″	5′ 0″ to 444′ 3″
36.	Slate, sandstone, and slate, ...	35′ 0″ to [illegible]′ 10″	[illegible] 10″ to 479′ 1″
37.	COOPER OR F BED, (coal, bone, and slate,)	10′ 0″ to 491′ 10″	9′ 11″ to 489′ 0″
38.	Slate, curly slate, coal, and slate, ...	8′ 0″ to 499′ 10″	7′ 11″ to 496′ 11″
39.	Sandy slate, ...	12′ 0″ to 511′ 10″	11′ 11″ to 508′ 10″
40.	Dark sandstone, . .	17′ 3″ to 529′ 01″	17′ 2″ to 526′ 0′
41.	BENNETT, FORGE, OR E BED, ...	6′ 9″ to 535′ 10″	6′ 9″ to 532′ 9″
42.	Slate, ...	3′ 0″ to 538′ 10″	3′ 0″ to 535′ 9″
43.	Short fracture sandstone, ...	30′ 6″ to 569′ 4″	30′ 4″ to 566′ 1″
44.	COAL, dirt, and bone.		

Splits of Baltimore bed. (Nos. 35–41)

See Columnar Section Sheet, No. IV, and Mine Sheet No. III.

Susquehanna Coal Co.

(Reported by Susquehanna Coal Co.)

	No. of strata.	*Description.*	*Thicknesses measured vertically.*	*Thicknesses perpendicular to dip.*
	1.	Wall and timbering,	28′ 0″ to 28′ 0″	28′ 0″ to 28 0″
	2.	Slate, sandstone, and sla e, .	25′ 0″ to 48′ 0″	24 9″ to 47′ 9″
	3.	COOPER OR F BED. Dip 8° S., .	8′ 0″ to 56′ 0″	7′ 11″ to 55′ 8″
	4.	Slate, curly slate, coal, and stone, .	5′ 0″ to 61′ 0″	4′ 11″ to 60′ 7″
	5.	Sandy slate, ...	13′ 0″ to 74′	12′ 10″ to 73′ 5″
	6.	Dark sandstone, . .	14′ 6″ to 88′ 6″	14′ 4″ to 87′ 9″
	7.	BENNETT OR E BED. Dip 10° S., . . .	5′ 6″ to 94′ 0″	5′ 5″ to 93′ 2″
	8.	Slate, ...	3′ 0″ to 97′ 0″	2′ 11″ to 96′ 1″
	9.	Short fracture sandstone, . . .	30′ 6″ to 127′ 6″	21′ 7″ to 117′ 8″
	10.	COAL, dirt, and bone,	6″ to 128′ 0″	6″ to 118′ 2″
	11.	Hard bone sandstone	17′ 0″ to 145′ 0″	12′ 0″ to 130′ 2″
	12.	Fine conglomerate. Dip at 150′ 45° N. W., . .	55′ 0″ to 200′ 0″	42′ 1″ to 172′ 3″
	13.	Hard black sandstone, ...	42′ 4″ to 242′ 4″	32′ 6″ to 204′ 9″
Twin or D Bed.	14.	COAL, ...	6′ 4″ to 248′ 8″	6′ 3″ to 211′ 0″
Twin or D Bed.	15.	Slate, ...	6′ 6″ to 255′ 2″	6′ 5″ to 217′ 5″
Twin or D Bed.	16.	COAL. Dip 5° S. E.,	7′ 2″ to 262′ 4″	7′ 1″ to 224′ 6″
	17.	Slate, ...	19′ 0″ to 281′ 4″	18′ 10″ to 243′ 4″
	18.	COAL, ...	2′ 4″ to 283′ 8″	2′ 4″ to 245′ 8″
	19.	Slate and short fracture sandstone, .	30′ 8″ to 314′ 4″	30′ 4″ to 276′ 0″
	20.	Hard quartz rock, .	22′ 0″ to 336′ 4″	21′ 9″ to 297′ 9″
	21.	Slate and short fracture sandstone, .	26′ 4″ to 362′ 8″	26′ 1″ to 323′ 10″
	22.	Firm sandstone, . .	12′ 0″ to 374′ 8″	11′ 11″ to 335′ 9″
	23.	COAL, . .	2′ to 374′ 10″	2″ to 335′ 11″
	24.	Sandy slate and hard sandstone, .	13′ 10″ to 388′ 8″	13′ 8″ to 349′ 7″
	25.	Close hard sandstone	15′ 0″ to 403′ 8″	14′ 10″ to 364′ 5″
	26.	Slate, ...	4′ 6″ to 407′ 8″	3′ 11″ to 368′ 4″
	27.	ROSS OR C BED. Dip 15°, ...	5′ 8″ to 413′ 4″	5′ 6″ to 373′ 10″
	28.	Hard sandstone, . .	12′ 4″ to 425′ 8″	11′ 11″ to 385′ 9″
	29.	Slaty sandstone, firm	17′ 0″ to 442′ 8″	16′ 5′ to 402′ 2″
	30.	3-FOOT BED. Dip 12° S., ...	3′ 0″ to 445′ 8″	2′ 11″ to 405′ 1″
	31.	Slate and hard bastard conglomerate,	53′ 0″ to 498′ 8″	51′ 10″ to 456′ 11″

No. of strata.	Description.	Thicknesses measured horizontally.	Thicknesses perpendicular to dip.
32.	COAL. Dip 15° N., .	3' 2" to 501' 10"	3 1" to 460' 0"
33.	Slaty sandstone and bastard conglomerate, . .	38' 0" to 539 10"	37' 2" to 497' 2"
34.	COAL. Dip 5° N., .	2' 0" to 541 10"	2' 0" to 499' 2"
35.	Slate, .	5" to 542' 3"	5" to 499' 7"
36.	Bastard conglomerate, .	36' 11' to 579' 2"	[illegible] 9" to 536' 4"
37.	BUCK MOUNTAIN OR B BED, ...	10' 0" to 589' 2"	10' 0" to 546' 4"
38.	Slate, ...	13' 0" to 6 2' 2"	12' 11" to 559' 3"
39.	RED ASH BED, . .	6' 0" to 608 2"	6' 0" to 565' 3"

See Columnar Section Sheet, No. IV, and Mine Sheet, No. III.

Columnar Section to illustrate the Coal Measures on Geological and Mine Sheet, No. IV.

Section of Hanover Diamond Drill Bore-hole from Surface to Conglomerate.

L. & W B. C. Co.

(Reported by L. & W B. C. Co.)

No. of strata.	Description.	Thicknesses measured horizontally.	Thicknesses perpendicular to dip.
1.	Yellow clay, . . .	3' 0" to 3' 0"	3' 0" to 3' 0"
2.	Quicksand, ...	9' 0" to 12' 0"	9' 0" to 12' 0"
3.	Sandstone, dip flat,	38' 0" to 50' 0"	38' 0" to 50 0"
4.	Slate, ...	9' 0" to 59' 0"	9' 0" to 59' 0"
5.	Sandstone, ...	17' 0" to 76' 0"	17' 0" to 76' 0"
6.	Rib slate, ...	20' 0" to 96' 0"	20' 0" to 96' 0"
7.	COAL BED, . . .	4' 0" to 100' 0"	4' 0" to 100' 0"
8.	Slate, ...	14' 0" to 114' 0"	14' 0" to 114' 0"
9.	COAL BED, ...	6' 0" to 120' 0"	6' 0" to 120' 0"
10.	Slate, ...	2' 0" to 122' 0"	2' 0" to 122' 0"
11.	Sandstone, ...	24' 0" to 146' 0"	24' 0" to 146' 0"
12.	Slate, ...	27' 0" to 173' 0"	27' 0" to 173' 0"
13.	Sandstone, ...	20 0" to 193' 0"	20' 0" to 193' 0"
14.	Slate, ...	10' 0" to 203' 0"	10' 0" to 203' 0"
15.	COAL BED, ...	3' 0" to 206' 0"	3' 0' to 206' 0"
16.	Slate, . . .	3' 0" to 209' 0"	3' 0" to 209' 0"
17.	Gray sandstone, .	12' 0" to 221' 0"	12' 0" to 221' 0"
18.	Dark sandstone, . .	25' 0" to 246' 0"	25' 0" to 246' 0"
19.	Dark-gray sandstone	29' 0" to 275' 0"	29' 0" to 275' 0"
20.	Slate, ...	3' 0" to 278' 0"	3' 0" to 278' 0"
21.	COAL BED, ...	9' 6' to 287' 6'	9' 6" to 287' 6"

No. of strata.	Description.	Thicknesses measured horizontally.	Thicknesses perpendicular to dip.
22.	Slate, ...	52′ 6″ to 340′ 0″	52′ 6″ to 340′ 0″
23.	Sandstone, ...	10′ 0″ to 350′ 0″	10′ 0″ to 350′ 0″
24.	Slate, ...	12′ 0″ to 362′ 0″	12′ 0″ to 362′ 0″
25.	COAL BED, ...	9′ 0″ to 371′ 0″	9′ 0″ to 371′ 0″
26.	Slate, ...	2′ 0″ to 373′ 0″	2′ 0″ to 373′ 0″
27.	Sandstone, ...	3′ 0″ to 376′ 0″	3′ 0″ to 376′ 0″
28.	Light-blue slate, . .	80′ 0″ to 456′ 0″	80′ 0″ to 456′ 0″
29.	COAL BED, ...	8′ 6″ to 464′ 6″	8′ 6″ to 464′ 6″
30.	Slate, ...	14′ 6″ to 479′ 0″	14′ 6″ to 479′ 0″
31.	Gray sandstone, . .	120′ 0″ to 599′ 0″	120′ 0″ to 599′ 0″
32.	Slate, ...	4′ 0″ to 603′ 0″	4′ 0″ to 603′ 0″
33.	COAL BED, ...	3′ 0″ to 606′ 0″	3′ 0″ to 606′ 0″
34.	Slate, ...	16 0″ to 622′ 0″	16′ 0′ to 622′ 0″
35.	COAL BED, . .	2′ 0″ to 624′ 0″	2′ 0″ to 624′ 0″
36.	Slate, ...	3′ 0″ to 627′ 0″	3′ 0″ to 627′ 0″
37.	Rough gray sandstone, ...	22′ 0″ to 649′ 0″	22′ 0″ to 649′ 0′
38.	White pebbles, . .	2′ 0″ to 651′ 0″	2′ 0″ to 651′ 0′
39.	Slate, ...	2′ 0″ to 653′ 0′	2′ 0″ to 653′ 0″
40.	Rough sandstone, .	24′ 0″ to 677′ 0″	24′ 0″ to 677′ 0″
41.	Fine gray sandstone,	7′ 0″ to 684′ 0″	7′ 0″ to 684′ 0″
42.	Slate, ...	4′ 0″ to 688′ 0″	4′ 0″ to 688′ 0″
43.	Fine gray sandstone,	23′ 0″ to 711′ 0″	23′ 0″ to 711′ 0′
44.	White spar, ...	2′ 0″ to 713′ 0″	2′ 0″ to 713′ 0″
45.	Fine-grained sandstone, ...	6′ 0″ to 719′ 0″	6′ 0″ to 719′ 0″
46.	Conglomerate, . . .	36′ 0″ to 755′ 0″	36′ 0″ to 755′ 0″

See Columnar Section Sheet, No. IV, and Mine Sheet, No. IV.

Columnar Section to illustrate the Coal Measures on Geological and Mine Sheet, No. V.

Section of Plymouth Shaft, No. 2, and Rope Drill Bore-hole from Surface through Red Ash Bed.

D. & H. C. Co.

(Reported by D. & H. C. Co.)

No. of strata.	Description.	Thicknesses measured vertically.	Thicknesses perpendicular to dip.
1.	Soil and clay, . . .	60′ 0″ to 60′ 0″	60′ 0″ to 60′ 0″
2.	HUTCHISON BED, .	6′ 6″ to 66′ 6″	6′ 5″ to 66′ 5′
3.	Soil and clay, . .	4′ 6″ to 71′ 0″	4′ 5″ to 70′ 10″
4.	Sandstone and slate	85′ 0″ to 156′ 0″	83′ 8″ to 154′ 6″
5.	COAL, dip 10° S., .	2′ 6″ to 158 6″	2′ 6″ to 157′ 0″
6.	Slate, ...	7′ 6″ to 166′ 0″	7′ 5″ to 164′ 5″
7.	LANCE BED, . . .	6′ 6″ to 172′ 6	6′ 5″ to 170′ 10″

No. of strata.	Description.	Thicknesses measured horizontally.		Thicknesses perpendicular to dip.	
8.	Sandstone and slate	35′ 0″	to 207′ 6″	34′ 5″	to 203′ 3″
9.	COAL,	8″	to 206′ 2″	8″	to 205′ 11″
10.	Sandstone and slate	41′ 3″	to 249′ 5″	40′ 6″	to 246′ 5″
11.	HILLMAN BED,	10′ 7″	to 260′ 0″	10′ 5″	to 256′ 10″
12.	Sandstone,	31′ 7″	to 291′ 7″	29′ 1″	to 283′ 11″
13.	COAL,	1′ 6″	to 293′ 1″	1′ [illegible]	to 287′ 6″
14.	Slate,	7′ 0″	to 300′ 1″	6′ 11″	to 294′ 4″
15.	"G" BED,	11′ 5″	to 311′ 6″	11′ 3″	to 305′ 7″
16.	Slate and sandstone	14′ 2″	to 325′ 8″	13′ 10″	to 319′ 5″
17.	Sandstone and slate	79′ 10″	to 405′ 6″	79′ 4″	to 398′ 9″
18.	COAL,	2′ 0″	to 407′ 6″	[illegible]	to 400′ 9″
19.	Slate,	21′ 3″	to 428′ 9″	20′ 11″	to 421′ 8″
20.	FIVE-FOOT OR "F" BED,	6′ 9½″	to 435′ 6½″	[illegible] 7″	to 428′ 3″
21.	Sandstone,	16′ 10″	to 452′ 4½″	16′ 7″	to 444′ 10″
22.	COOPER BED,	9′ 7″	to 461′ 11½″	[illegible]	to 454′ [illegible]
23.	Slate,	3′ 11″	to 465′ 10½″	3 9″	to 457′ 11″
24.	Hard sandstone,	127′ 10″	to 593′ 8½″	125′ [illegible]	to 583′ 8″
25.	BENNETT BED,	16′ 3½″	to 610′ 0″	15′ 9″	to 599′ 5″
26.	Fire-clay,	14′ ½″	to 624′ ½″	13′ 9″	to 613′ 2″
27.	Slated fire-clay,	14′ 7½″	to 638′ 8″	13′ 7″	to 626′ [illegible]
28.	Sandstone,	9′ 10″	to 648′ 6″	9′ 8″	to 636′ 5″
29.	Slate,	14′ 10¾″	to 663′ 4¼″	14′ 7″	to 651′ 0″
30.	"D" OR ROSS BED,	3′ 0″	to 666′ 4¼″	2′ 11″	to 653′ 11″
31.	Black slate,	2′ 4″	to 668′ 8¼″	2′ 3″	to 656′ 2″
32.	Hard sandstone,	25′ 9″	to 694′ 5¼″	25′ 6″	to 681′ 8″
33.	Slate,	[illegible] 0″	to 696′ 5¼″	1′ 11″	to 683′ 7″
34.	Soft sandstone,	3′ 9″	to 700′ 2¼″	3′ 8″	to 687′ 3″
35.	Slate and fire-clay,	2′ 0″	to 702′ 2¼″	1′ 11″	to 689′ 2″
36.	COAL,	2′ 2″	to 704′ 4¼″	2′ 1″	to 691′ 3″
37.	Hard slate,	11′ 4″	to 715′ 8¼″	11′ 2″	to 702′ [illegible]
38.	Soft sandstone,	8′ 9″	to 724′ 5¼″	8′ 7″	to 711′ [illegible]
39.	Hard sandstone,	13′ 7¾″	to 738′ 1″	[illegible] 6″	to 724′ 6″
40.	Slate,	1′ 7″	to 739′ 8″	1′ [illegible]	to 726′ 0″
41	Soft sandstone,	1′ 3½″	to 740′ 11½″	1′ 2″	to 727′ 2″
42.	Hard sandstone,	28′ 6½″	to 769′ 6″	[illegible] 3″	to 755′ 5″
43.	Very hard sandstone,	17′ 0″	to 786′ 6″	16′ 10″	to 772′ [illegible]
44.	"C" BED,	9′ 10″	to 796′ 4″	9′ 7″	to 781′ 10″
45.	Fire-clay with iron balls,	24′ 8¼″	to 821′ ¼″	24′ 7″	to 806′ [illegible]
46.	Slate,	5′ 4½″	to 826′ 4¾″	[illegible] 3″	to 811′ 8″
47.	Soft sandstone,	4′ 7¼″	to 831′ 0″	[illegible] 6″	to 816′ 2″
48.	Sandstone,	16′ 7½″	to 847′ 7½″	16′ 4′	to 832′ 6″
49.	"B" OR RED ASH BED,	23′ [illegible]	to 871′ 3½″	23′ 3″	to 855′ 9″
50.	Sandstone,	10′ 0″	to 881′ 3½″	[illegible] 10″	to 865′ 7″

See Columnar Section Sheet, No. III, and Mine Sheet, No. V.

Columnar Sections to Illustrate the Coal Measures on Geological and Mine Sheet No. VI.

Section of Stanton (No. 7) Shaft from Surface through Coal Bed at 697′ 1″ to Hard Rock 732′ 6″.

L. & W. B. C. Co.

(Reported by L. & W. B. C. Co.)

No. of strata.	*Description.*	*Thicknesses measured vertically.*	*Thicknesses perpendicular to dip.*
1.	Cribbing, ...	31′ 0″ to 31′ 0″	31′ 0″ to 31′ 0″
2.	Sandstone, dip 9° S.,	14′ 0″ to 45′ 0″	13′ 10″ to 44′ 10″
3.	Slate, ...	3″ to 45′ 3″	0′ 3″ to 45′ 1″
4.	Sandstone, ...	23′ 9″ to 69′ 0″	23′ 5″ to 68′ 6″
5.	Black slate, ...	9′ 0″ to 78′ 0″	8′ 11″ to 77′ 5″
6.	COAL BED, ...		
7.	Dirt and slate, . .	12′ 8″ to 90′ 8″	12′ 7″ to 90′ 0″
8.	COAL BED, ...		
9.	Soft sandstone, . .	8′ 4″ to 99′ 0″	8′ 3″ to 98′ 3″
10.	Gray slate, ...	4′ 0″ to 103′ 0″	3′ 11″ to 102′ 2″
11.	Hard rock, ...	1′ 0″ to 104′ 0″	1′ 0″ to 103′ 2″
12.	Soft sandstone and sand mixed, . . .	49′ 0″ to 153′ 0″	48′ 5″ to 151′ 7″
13.	SEVEN-FOOT BED, .	5′ 6″ to 158′ 6″	5′ 6″ to 157′ 1″
14.	Sandstone, ...	6′ 6″ to 165′ 0″	6′ 5″ to 163′ 6″
15.	Slate, ...	13′ 0″ to 178′ 0″	12′ 10″ to 176′ 4″
16.	Fire-clay, ...	2′ 0″ to 180′ 0″	2′ 0″ to 178′ 4″
17.	Gray slate, ...	10′ 0″ to 190′ 0″	9′ 10″ to 188′ 2″
18.	Sandstone, ...	11′ 0″ to 201′ 0″	10′ 10″ to 199′ 0″
19.	Slate and fire-clay,	22′ 0′ to 223′ 0″	21′ 9″ to 220′ 9″
20.	Sandstone, ...	1′ 0″ to 224′ 0″	1′ 0″ to 221′ 9″
21.	Slate, ...	2′ 0″ to 226′ 0′	2′ 0″ to 223′ 9″
22.	Fire-clay, ...	1′ 0″ to 227′ 0″	1′ 0″ to 224′ 9″
23.	COAL, ...	2′ 0″ to 229′ 0″	2′ 0″ to 226′ 9″
24.	Soft slate, ...	8′ 0″ to 237′ 0″	7′ 11″ to 234′ 8″
25.	Hard sandstone, . .	24′ 0″ to 261′ 0″	23′ 8″ to 258′ 4″
26.	Slate, ...	4′ 0″ to 265′ 0″	3′ 11″ to 262′ 3″
27.	Fire-clay, ...	1′ 0″ to 266′ 0″	1′ 0″ to 263′ 3″
28.	KIDNEY BED, . . .	5″ to 271′ 0″	4′ 11″ to 268′ 2″
29.	Slate, ...	6″ to 271′ 6″	0′ 6″ to 268′ 8″
30.	Sandstone and slate mixed, ...	27′ 6″ to 299′ 0″	27′ 2″ to 295′ 10″
31.	Sandstone, ...	28′ 0″ to 327′ 0″	27′ 8″ to 323′ 6″
32.	Fire-clay, ...	1′ 0″ to 328′ 0″	1′ 0″ to 324′ 6″
33.	HILLMAN BED, . .	6′ 8″ to 334′ 8″	6′ 7″ to 331′ 1″
34.	Soft sandstone, . .	14′ 6″ to 349′ 2″	14′ 4″ to 345′ 5
35.	Hard sandstone, . .	33′ 0″ to 382 2″	32′ 7″ to 378′ 0″
36.	Slate, ...	2′ 0″ to 384′ 2″	2′ 0″ to 380′ 0″

No. of strata.	*Description.*	*Thicknesses measured horizontally.*	*Thicknesses perpendicular to dip.*
37.	Bone and slate, . .	3' 0" to 387' 2"	3' 0" to 383' 0"
38.	Slate, ...	3' 0" to 390' 2"	3' 0" to 386' 0"
39.	LODGMENT BED, .	7' 0" to 397' 2"	6' 11" to 392' 11"
40.	Soft sandstone, dip 45° N., ...	10' 0" to 407' 2"	7' 1" to 400' 0"
41.	Hard sandstone, . .	58' 6" to 465 8"	41' 4" to 441' 4"
42.	Gray slate, ...	15' 0" to 480' 8"	10' 7" to 451' 11"
43.	COAL BED, ...	7' 5" to 488' 1"	5' 3" to 457' 2"
44.	Sandstone, ...	11' 0" to 499' 1"	7' 9" to 464' 11"
45.	Slate, ...	11' 0" to 510' 1"	7' 9" to 472' 8"
46.	Sandstone, ...	21' 0" to 531' 1"	14" 10' to 487' 6"
47.	Soft gray slate, . . .	5' 0" to 536' 1"	3 6" to 491' 0"
48.	Hard sandstone, . .	50' 0" to 586' 1"	35' 4" to 526' 4"
49.	Slate, ...	2' 8" to 588' 9"	1' 11" to 528' 3"
50.	Sandstone, ...	10' 0" to 598' 9"	7' 1" to 535' 4"
51.	Black slate, ...	5' 0" to 603' 9"	3' 6" to 538' 10"
52.	Dark sandstone, .	21' 0" to 624' 9"	14' 10" to 553' 8"
53.	Fine black slate, . .	9' 1" to 633' 10"	6' 5" to 560' 1"
54.	COAL BED, ...	7' 7" to 641' 5"	5' 5" to 565' 6"
55.	Slate, ...	6' 0" to 647' 5"	4' 3" to 569' 9"
56.	Sandstone, ...	1' 0" to 648' 5"	0' 8" to 570' 5"
57.	Slate, ...	6' 0" to 654' 5"	4' 3" to 574' 8"
58.	Sandstone, ...	39' 0" to 693' 5"	27' 7" to 602' 3"
59.	Slate, ...	1' 6" to 694' 11"	1' 1" to 603' 4"
60.	Sandstone, . .	3' 8" to 698' 7"	2' 7" to 605' 11"
61.	Dark slate, ...	16' 8" to 715' 3"	14' 2" to 620' 1"
62.	Sandstone, ...	3' 0" to 718' 3"	2' 1" to 622' 2"
63.	Black slate, ...	8' 3" to 726' 6"	5' 10" to 628' 0"
64.	Sandstone, . . .	6' 9" to 733' 3"	4' 9" to 632' 9"
65.	Soft dark sandstone,	5' 0" to 738' 3"	3' 6" to 636 3"
66.	Soft slate, . . .	1 6" to 739' 9"	1' 1" to 637' 4"
67.	Bone (Rider,) . . .	1' 0" to 740' 9"	0' 8" to 638' 0"
68.	Fire-clay, ...	2' 0" to 742' 9"	1' 5" to 639' 5"
69.	BALTIMORE BED, .	21' 4" to 765' 1"	15' 9" to 655' 2"
70.	Hard sandstone, . .	54' 4" to 819' 5"	38' 5" to 693' 7"
71.	Black slate, ...	5' 6" to 824' 11"	3' 11" to 697' 6"
72.	COAL, ...	3' 0" to 827' 11"	2' 1" to 699' 7"
73.	Black slate, ...	1' 8" to 829' 7"	1' 2" to 700' 9"
74.	Fire-clay, ...	7' 7" to 837' 2"	5' 4" to 706' 1"
75.	Rock, ...	38' 0" to 875' 2"	26' 10" to 732' 11"

See Columnar Section Sheet, No. II, and Mine Sheet, No. VI.

Section of Empire Shaft. No. 4, Inside Tunnel from Hillman Bed to Red Ash Bed.

L. & W. B. C. Co.

(Measured by Geological Survey.)

No. of strata.	*Description.*	*Thicknesses measured horizontally.*	*Thicknesses perpendicular to dip.*
1.	HILLMAN BED, . .		
2.	Sandstone, dip 56° N., ...	40' 11'' to 40' 11''	21' 0'' to 21' 0''
3.	Slate, ...	2' 4'' to 43' 3''	1' 2'' to 22' 2''
4.	COAL BED, ...	3' 2'' to 46' 5''	2' 0'' to 24' 2''
5.	Slate, ...	11' 1'' to 57' 6''	6' 0'' to 30' 2''
6.	Sandstone, ...	60' 9'' to 118' 3''	30' 0'' to 60' 2''
7.	Slate, ...	10' 5'' to 128' 8''	5' 3'' to 65' 5''
8.	COAL BED, dip 30° N., ...	10' 0'' to 138' 8''	4' 9'' to 70' 2''
9.	Slate, ...	11'' to 139' 7''	1' 0'' to 71' 2''
10.	Sandstone, ...	45' 1'' to 184' 8''	30' 0'' to 101' 2''
11.	Slate, dip 42° N., .	1' 5'' to 186' 1''	1' 6'' to 102' 8''
12.	Sandstone, ...	136' 1'' to 322' 2''	111' 0'' to 213' 8''
13.	Slate, ...	1' 10'' to 324'	2' 5'' to 216' 1''
14.	COAL BED, ...	5' 4'' to 329' 4''	4' 1'' to 220' 2''
15.	Slate, ...	1' 0'' to 330' 4''	1' 0'' to 221' 2''
16.	Sandstone, ...	67' 10'' to 398' 2''	49' 0'' to 270' 2''
17.	Slate, ...	5' 0'' to 403' 2''	3' 6'' to 273' 8''
18.	Dark sandstone, . .	27' 6'' to 430' 8''	14' 10'' to 288' 6''
19.	BALTIMORE BED, .	17' 9'' to 448' 5''	17' 2'' to 305' 8''
20.	Slate, dip 46° N., .	66' 3'' to 514' 8''	47' 6'' to 353' 2''
21.	Sandstone, with conglomerate, &c., .	47' 0'' to 561' 8''	18' 0'' to 371' 2''
22.	Hard sandstone,	111' 5'' to 673' 1''	43' 10'' to 415' 0''
23.	COAL BED, dip 20° N., ...	19' 7'' to 692' 8''	5' 8'' to 420' 8''
24.	Slate, ...	8' 9'' to 701' 5''	3' 0'' to 423' 8''
25.	Hard slaty sandstone, ...	44' 3'' to 745' 8''	17' 9'' to 441' 5''
26.	COAL BED, dip, 18° N., ...	19' 6'' to 765' 2''	1' 3'' to 442' 8''
27.	Slate, ...	22' 6'' to 787' 8''	7' 6'' to 450' 2''
28.	Sandstone with conglomerate, . . .	144' 4'' to 932'	45' 6'' to 495' 8''
29.	Hard sandstone with conglomerate, dip 18° N., ...	60' 1'' to 992' 1''	18' 6'' to 514' 2''
30.	Hard slate, ...	1' 0'' to 993' 1''	1' 0'' to 515' 2''
31.	Fine conglomerate, dip 26°, ...	97' 4'' to 1090' 5''	41' 10'' to 557' 0''
32.	ROSS BED, ...	20' 3'' to 1110' 8''	7' 1'' to 564' 1''
33.	Slate, ...	15' 9'' to 1126' 5''	4' 6'' to 568' 7''

No. of strata.	Description.	Thicknesses measured horizontally.	Thicknesses perpendicular to dip.
34.	Hard sandstone, dip 18° N., ...	183′ 3″ to 1309′ 8″	56′ 0″ to 624′ 7″
35.	Slate, . . .	30′ 11″ to 1340′ 7″	9′ 9″ to 631′ 4″
36.	RED ASH BED, (TOP BENCH.) .	21′ 1″ to 1361′ 8″	8′ 4″ to 642′ 8″
37.	Slate, dip 22° N., .	28′ 0″ to 1389 8′	11′ 0″ to 653′ 8′
38.	Hard sandstone, . .	43′ 6″ to 1433′ 2″	12′ 1″ to 665′ 9″
39.	RED ASH BED, (BOTTOM BENCH,) . .	28′ 6″ to 1461 8″	13′ 11″ to 679′ 8″

See Columnar Sheet No. II and Mine Sheet No. VIII.

Columnar Section to Illustrate the Coal Measures on Geological and Mine Sheet No. VII.

Section of Kingston, No. 3, Shaft, from Surface to Bennett Bed.

K. C. Co.

(Reported by Kingston Coal Co.)

No. of strata.	Description.	Thicknesses measured vertically.	Thicknesses perpendicular to dip.
1.	Loam, ...	11′ 0″ to 11′ 0″	11′ 0″ to 11′ 0″
2.	Sandstone, dip, 8° S.,	32′ 0″ to 43′ 0″	31′ 6″ to 42′ 6″
3.	ORCHARD BED, . . .	4′ 0″ to 47′ 0″	3′ 11′ to 46′ 5″
4.	Sandstone, ...	98′ 0″ to 145′ 0″	96′ 11″ to 143′ 4″
5.	LANCE BED, ...	7′ 0″ to 152′ 0″	6′ 11″ to 150′ 3″
6.	Sandstone, ...	76′ 0″ to 228′ 0″	75′ 2″ to 225′ 5″
7.	COOPER BED, ...	7′ 4″ to 235′ 4″	7′ 3″ to 232′ 8″
8.	Slate, ...	22′ 0″ to 257′ 4″	21′ 9″ to 254′ 5″
9.	BENNETT BED, . . .	14′ 0″ to 271′ 4″	13′ 10″ to 268′ 3′
10.	Fire-clay, ...	5′ 0″ to 276′ 4″	4′ 11″ to 273′ 2″
11.	Sandstone, ...	31′ 6″ to 307′ 10″	31′ 2″ to 304′ 4″
12.	COAL BED, ...	5′ 8″ to 313′ 6″	5′ 7″ to 309′ 11″
13.	Sandstone and balls of ore, ...	20′ 0″ to 333′ 6″	19′ 10″ to 329′ 9″
14.	Slate, ...	25′ 6″ to 359′ 0″	25′ 3″ to 355′ 0″
15.	COAL, ...	2′ 0″ to 361′ 0″	1′ 11″ to 356′ 11″
16.	Sandstone, ...	43′ 6″ to 404′ 6″	43′ 0″ to 399′ 11″
17.	Slate, ...	23′ 0″ to 427′ 6″	22′ 9″ to 422′ 8″
18.	COAL, ...	2′ 6″ to 430′ 0″	2′ 6″ to 425′ 2″
19.	Sandstone, ...	13′ 6″ to 443′ 6″	13′ 4″ to 438′ 6″

No. of strata.	*Description.*	*Thicknesses measured horizontally.*	*Thicknesses perpendicular to dip.*
20.	ROSS BED, ...	9′ 0″ to 452′ 6″	8′ 11″ to 447′ 5″
21.	Fire-clay, ...	4′ 0″ to 456′ 6″	3′ 11″ to 451′ 4′
22.	Slate, ...	24′ 0″ to 480′ 6″	23′ 9″ to 475′ 1″
23.	Sandstone, ...	43′ 0′ to 523′ 6″	42′ 6″ to 517′ 7′
24.	Slate, ...	11′ 0″ to 534′ 6″	10′ 10″ to 528′ 5′
25.	RED ASH BED,	7′ 0″ to 541′ 6″	6′ 11″ to 535 4

See Columnar Section Sheet No. III and Mine Sheet No. VII.

Columnar Sections to illustrate the Coal Measures on Geological and Mine Sheet, No. VIII.

Section of Conyngham Shaft and Rope Drill Bore-hole from Surface to 78′ 9″ below the Red Ash Bed.

D. & H. C. Co.

(Reported by D. & H. C. Co.)

	No. of strata.	*Description.*	*Thicknesses measured vertically.*	*Thicknesses perpendicular to dip.*
	1.	Masonry, ...	21′ 6′ to 21 6	21 6 to 21 6
	2.	Fine sandstone, . .	3′ 6″ to 25′ 0	3′ 3″ to 24′ 9
	3.	Fine sandstone, dip 24° N., ...	20′ 9″ to 45′ 9″	18′ 11″ to 43′ 8′
	4.	Fine slate, ...	12′ 3″ to 58′ 0″	11′ 3″ to 54′ 11′
	5.	Sandstone, ...	7 7″ to 65′ 7″	6 11′ to 61′ 10″
K BED.	6.	COAL, dip, 13½° N.,	3′ 8″ to 69′ 3″	3 7″ to 65′ 5″
K BED.	7.	Slate rock, ...	3′ 7″ to 72′ 10″	3′ 6″ to 68′ 11′
K BED.	8.	COAL and slate, dip, 18½° N., ...	4 4″ to 77′ 2″	4′ 1″ to 73′ 0
	9.	Slate rock, ...	15′ 0″ to 92′ 2″	14′ 3″ to 87′ 8
	10.	Sandstone, dip, 16° N., ...	20′ 6″ to 112′ 8″	19′ 8″ to 106′ 11″
	11.	Pebble rock, dip, 11° N., ...	11′ 1″ to 123′ 9″	10′ 10″ to 117′ 9″
	12.	Black sandstone, dip, 11° N., ...	13′ 0″ to 136′ 9″	12′ 9″ to 130′ 6′
	13.	Slate rock, dip, 11° N., ...	3′ 2″ to 139′ 11″	3′ 1″ to 133′ 7″
	14.	J. SEVEN-FOOT OR ABBOTT BED, . .	4′ 7″ to 144′ 6″	4′ 6″ to 138′ 1′
	15.	Slaty sandstone, dip, 32° N., ...	60′ 5″ to 204′ 1″	51′ 3″ to 189′ 4
	16.	Pebble rock, ...	12′ 2′ to 217 1′	10′ 3″ to 199′ 7

No. of strata.	*Description.*	*Thicknesses measured horizontally.*	*Thicknesses perpendicular to dip.*
17.	Gray sandstone, dip, 23½° N., ...	16′ 6″ to 233′ 7′	15′ 2″ to 214′ 9″
18.	I. KIDNEY OR BOWKLEY BED, ...	5′ 0″ to 238′ 7″	4′ 7″ to 219′ 4″
19.	Slate, ...	18′ 2″ to 256 9″	16′ 7″ to 235′ 11″
20.	Pebble rock, . . .	31′ 2″ to 287′ 11″	28′ 6″ to 264′ 5″
21.	Black slate, ...	7′ 3″ to 295′ 2′	6′ 7″ to 271′ 0″
22.	H. OR HILLMAN BED, ...	17′ 5″ to 312′ 7″	15′ 11′ to 286′ 11″
23.	Slate roof, ...	8′ 2″ to 320′ 9″	7′ 5″ to 294′ 4″
24.	Pebble rock, ...	55′ 2′ to 375′ 11″	50′ 6″ to 344′ 10′
25.	Black slate, dip, 51° N., ...	1′ 8″ to 377′ 2″	9″ to 345′ 7″
26.	Pebble rock, dip, 40½° N., ...	106′ 0″ to 483′ 2″	80′ 7″ to 426′ 2″
27.	Slate roof, ...	11′ 5″ to 494′ 7″	10′ 3″ to 436′ 5″
28.	G. BED, ...	3′ 1″ to 497′ 8″	2′ 8″ to 439′ 1″
29.	Black slate, sand, COAL, ...	2′ 0″ to 499′ 8″	1′ 9′ to 440′ 10″
30.	Fine dark sandstone	33′ 9″ to 533 5″	30′ 4″ to 471′ 2″
31.	Micaceous fine sandstone, ...	17′ 9″ to 551′ 2′	15′ 10″ to 487′ 0″
32.	Fine dark sandstone	9′ 3″ to 560′ 5″	8′ 3″ to 495′ 3″
33.	Dark sandstone and COAL, ...	1′ 0″ to 561′ 5′	11″ to 496′ 2″
34.	F. BED, COAL and slate, ...	3′ 0″ to 564′ 5″	2′ 8″ to 498 10″
35.	Fine dark sand and fire-clay, ...	13′ 9″ to 578′ 2″	12′ 4″ to 511′ 2″
36.	Fine dark sand and fire-clay, ...	20 5″ to 598′ 7″	18′ 4″ to 529′ 6″
37.	Mica ironstone, fine and hard, ...	41′ 0″ to 639′ 7″	36′ 10″ to 566′ 4″
38.	Fine clay and ironstone, ...	7′ 0″ to 646′ 7″	6′ 3″ to 572 7″
39.	Fine micaceous ironstone, ...	60′ 0″ to 706′ 7′	53′ 10″ to 626 5″
40.	BALTIMORE BED, dip, 26° N., . . .	17′ 10″ to 724′ 5″	15′ 11″ to 642′ 4″
	Foot of shaft; bore-hole commences here.		
41.	Sandstone, ...	35′ 7″ to 760′ 0″	32′ 0″ to 674′ 4″
42.	Slate and COAL, . .	1′ 0″ to 761′ 0″	11″ to 675′ 3″
43.	Slate, ...	12′ 9″ to 773′ 9″	11′ 5″ to 686′ 8″
44.	Micaceous sandstone	36′ 0″ to 809′ 9″	32′ 4″ to 719′ 0″
45.	Slate and micaceous sandstone, ...	1′ 6″ to 811′ 3′	1′ 4″ to 720′ 4″
46.	Slate, COAL, COAL and slate, ...	1′ 6″ to 812′ 9″	1′ 4″ to 721′ 8″

No. of strata.	*Description.*	*Thicknesses measured horizontally.*	*Thicknesses perpendicular to dip.*
47.	Slate and fire-clay, .	12' 2" to 824' 11"	10' 10' to 782 6'
48.	Slate, ...	13' 0" to 837' 11"	11' 8" to 744 2
49.	Sandstone, ...	6' 10" to 844' 9"	6' 0" to 750' 2
50.	Micaceous sandstone	2' 3" to 847' 0"	1' 11" to 752' 1
51.	Slate, ...	5' 0" to 852' 0"	4 6" to 756' 7
52.	Slate and bone, . .	6' 2" to 858' 2"	5' 6" to 762' 1"
53.	Slate, ...	16' 2" to 874' 4"	14' 5" to 776' 6"
54.	Slate and bone, . .	5' 0" to 879' 4"	4' 6" to 781' 0'
55.	Slate, ...	6' 6" to 885' 10"	5' 10" to 786' 10'
56.	Micaceous sandstone	6' 5" to 892' 3"	5' 9" to 792' 7
57.	Pebble rock, ...	1' 0" to 893' 3"	11" to 793' 6"
58.	Micaceous sandstone	6' 0" to 899' 3'	5' 5" to 798' 11"
59.	Hard pebble rock,	51' 0" to 950' 3"	45' 9" to 844 8"
60.	Fire-clay and sandstone, ...	1' 6" to 951 9'	1' 4" to 846' 0"
61.	COAL and bone, . .	1 6' to 953' 3"	1' 4" to 847' 4"
62.	Sandstone, ...	111' to 1064' 3"	98' 8" to 946' 0"
63.	B. OR RED ASH BED, ...	13' 0' to 1077 3"	11' 8" to 957' 8"
64.	Spar rock, ...	87' 9" to 1165' 0"	78' 9" to 1036' 5"

See Columnar Section Sheet, No. I, and Mine Sheet, No. VIII.

Section of Baltimore Rope Drill Bore-Hole from Baltimore Bed to Red Ash Bed.

D. & H. C. Co.

(Reported by D. & H. C. Co.)

No. of strata.	*Description.*	*Thicknesses measured vertically.*	*Thicknesses perpendicular to dip.*
1.	BALTIMORE BED.		
2.	Sandstone, ...	98' 0" to 98' 0"	98' 0" to 98' 0"
3.	Slate, ...	7' 11" to 105' 11"	7' 11" to 105' 11"
4.	COAL, ...	2' 0" to 107' 11"	2' 0" to 107' 11"
5.	Slate, ...	1' 10' to 109' 9"	1' 10" to 109' 9"
6.	Sandstone, ...	23' 5" to 133' 2"	23' 5" to 133' 2"
7.	Slate, ...	5" to 133' 7"	5" to 133' 7"
8.	COAL, ...	8" to 134' 3"	8" to 134' 3"
9.	Slate, ...	2' 3" to 136' 6"	2' 3" to 136' 6"
10.	Sandstone, ...	85' 0" to 221' 6"	85' 0" to 221' 6"
11.	Slate, ...	6" to 222' 0"	6" to 222' 0"
12.	COAL, ...	3' 8" to 225' 8"	3' 8" to 225' 8"
13.	Slate, ...	6' 6" to 232' 2"	6' 6' to 232' 2"
14.	COAL, ...	10" to 233' 0"	10" to 233' 0"
15.	Slate, ...	21' 4" to 254' 4"	21' 4" to 254' 4"

No. of strata.	*Description.*	*Thicknesses measured horizontally.*	*Thicknesses perpendicular to dip.*
16.	COAL, ...	4′ 8″ to 259′ 0″	4′ 8″ to 259′ 0
17.	Slate, ...	6″ to 259′ 6	6″ to 259′ 6″
18.	COAL, ...	1′ 6″ to 261′ 0″	1′ 6″ to 261′ 0′
19.	Sandstone, ...	28′ 0″ to 289′ 0′	28 0″ to 289′ 0″
20.	RED ASH BED.		

See Columnar Section Sheet No. I and Mine Sheet No. VIII.

CHAPTER X.

Report on the Wyoming Valley Limestone-Beds.

By CHARLES A. ASHBURNER.

Accompanied by a Description of the Fossils Contained in the same.

By PROFESSOR ANGELO HEILPRIN.

Part I.

The occurrence of limestone-beds, interstratified with the shales, sandstones, and coal-beds of the Coal Measures (Formation No. XIII) in Pennsylvania is not unusual; on the contrary, they characterise all the bituminous measures in the State.

In the most recent coal measures, and the highest in the geological column, in Washington and Greene counties, there occur sixteen beds of limestone, with an aggregate thickness of about 100 feet, contained in a section of coal measures having a total thickness of about 1000 feet.

In the Upper Productive Measures, which extend from the bottom of those just referred to, down to and including the Pittsburgh coal-bed, having an aggregate thickness of 500 feet, there occur five prominent limestone-beds having a thickness of 105 feet.

In the Lower Barren Measures of Beaver county, which extend from the bottom of the Pittsburgh coal-bed down to the bottom of the Mahoning Sandstone, a distance of about 550 feet, there occur at least four well defined limestone-beds, the aggregate thickness of which is from 15 to 20 feet.

In the Lower Productive Measures, which contain the coal-beds mined extensively in many of the counties immediately back of the crest of the Allegheny mountains,

including the counties of Cambria, Clearfield, Jefferson, Elk, etc., there occur four easily recognized limestone-beds, having an aggregate thickness of from 15 to 20 feet, included in strata ranging from 300 to 400 feet in thickness. These coal measures extend from the Mahoning Sandstone down to the Pottsville Conglomerate.

In addition to these well defined limestone-beds, numbering in all 29, with an aggregate thickness of about 240 feet, and included in a vertical column of bituminous coal measures 2400 feet thick, there occur a number of sporadic or irregularly deposited limestone-beds of variable thicknesses; the thickness of any one of which, however, seldom exceeds 3 or 4 feet.

A vertical bore-hole in the extreme south-western corner of the State would pierce this entire column, with the included limestones and bituminous coal-beds. It is highly improbable, however, that all of these 29 beds would be found existing as limestones at any one locality, since we have found by experience that, while all the coal measure limestone horizons are remarkably persistent, yet, in special areas, the limestones thin down almost beyond recognition, or are entirely replaced by calcareous or argillaceous slate or shale, and sometimes even by sandstones which contain little or no lime.

In the Coal Measures of the anthracite region, however, the occurrence of limestone-beds is rare, and the only locality where clearly defined and persistent beds of limestone have been located by the Geological Survey is in the Wyoming valley. These beds are of special interest to geologists and palæontologists, on account of the number of fossil remains of water shells found in one of the most persistent of the beds, and which I have named the Mill Creek limestone-bed.

The existence of limestone in the coal measures of the Wyoming valley, particularly in the vicinity of Wilkes Barre, has been recognized for many years. A farmer on the farm of Judge Garrick Mallory is reported to have quarried limestone, over 15 or 20 years ago, from an outcrop on the south side of Mill creek, below the mouth of Laurel run,

at a locality to be referred to later, and to have gathered loose pieces of stone from the surrounding fields; this limestone was burned in an old kiln in the immediate vicinity for lime, which was used principally as a fertilizer.

Dr. Charles F. Ingham and Mr. Chris. H. Scharar, prominent and active members of the Wyoming Historical and Geological Society, together with the late Mr. Harrison Wright, secretary of the society, and other members, have made an interesting collection of fossil specimens from an outcrop of one of these Wilkes Barre limestone beds, near the old Hollenback dam across Mill creek, at the head of a supply race of the now abandoned New York and Pennsylvania canal. This limestone outcrop is on the Mill Creek bed.

Shortly after the commencement of the Anthracite Survey in 1880, I had the pleasure of examining this collection of fossils with Mr. Wright in the society's rooms at Wilkes Barre, and subsequently had an opportunity of visiting the locality on Mill creek, from which these fossils were obtained, in company with both Mr. Wright and Dr. Ingham. The importance of having a determination made of the genera and species of these fossil forms, which were currently reported to be distinctly Permian, was early appreciated by Professor Lesley. The fragmentary character of the specimens, together with the questionable species of many of them, made it necessary that the fossils should be subjected to the scrutiny of an expert palæontologist.

The problems in practical geology which have occupied the attention of the members of the Survey corps, and which have had such an important bearing upon the economical development of the mineral resources of the State, have been so numerous, that the State appropriations made for the Survey have not permitted of the large number of fossil specimens which have been collected by the Survey assistants being studied and reported on by an expert palæontologist.

The great number of fossil specimens which have been collected, particularly in the central and north-western parts of the State, have been catalogued as to their locality and the lithological characteristics of the strata in which

they were found; and, in accordance with a special act of the Legislature, have been deposited with the Academy of Natural Sciences in Philadelphia. The Wilkes Barre fossil specimens in the possession of the Wyoming Historical and Geological Society, and those privately held by Mr. Schaarer, were placed at the disposal of the Survey in 1880 for examination. After a cursory examination of these specimens, I was convinced that the species could not be satisfactorily determined, for the reasons already assigned, except by a specialist.

At the request of Professor Lesley the specimens were examined at different times by two of our field geologists, who had given considerable time to the study of Palæozoic fossils. Failure in one case to identify a number of the forms, and, in the other case, to assign questionable names to a number of them, led finally to Professor Angelo Heilprin, professor of invertebrate palæontology at the Philadelphia Academy of Natural Sciences, being induced to undertake the examination. Professor Heilprin's time being almost entirely taken up with work previously engaged upon, the progress made in the careful and systematic study of the Wilkes Barre fossils was necessarily slow. The thoroughness with which Professor Heilprin pursued his work, and the unquestioned correctness of his conclusions, which, however, differ largely from the conclusions of others who have previously examined the specimens, should be a source of congratulation, both to the Wyoming Society and the Survey, that no publications have been made prior to Professor Heilprin's determinations.

Those who have studied these fossils for a number of years have generally assigned them to the Permian formation. The occurrence of the Mill Creek limestone-bed, however, in which the fossils were found, inter-stratified with sandstones and shales included between two coal-beds of apparently undisputed Carboniferous age, made the study of the fossils all the more interesting, and their determination the more important.

The names assigned to the forms examined by Professor Heilprin, together with careful descriptions and references,

makes his paper (Part II), which follows, complete in itself, and it is only necessary to refer to the geological relationships of the limestones from which they were taken.

A more extended and careful examination of the outcrops of the Mill Creek limestone will no doubt reveal other specimens not contained in the specimens which have so far been found and examined.

In order to aid future explorers to identify specimens which they may find, photographs of the more distinct specimens were made, but failed to show with sufficient definition the details of the forms as they appear on the specimens themselves, so that independent drawings of the fossils, from the specimens and photographs combined, were made under Professor Heilprin's personal supervision. These drawings are reproduced on the accompanying page plates. On account of the indistinctness of some of the specimens, as represented on the page plates, and in order to permit students more easily to identify new specimens, other drawings, more complete in form, of the same specimens were made and are inserted in the text.

The Mill Creek limestone-bed outcrops along the north side of Mill creek, near the breast of the old Hollenback dam, and about midway between the River Street bridge and a bridge of the Lehigh Valley railroad, which crosses the creek immediately at its mouth.

The limestone is siliceous, ferruginous, and extremely hard, and from 1 foot to 15 inches thick.

It occurs between the Prospect shaft anticlinal, which runs due west from Prospect Shaft across the Susquehanna river, and the center of the Cemetery basin; the axis of the basin crosses River street about midway between Chestnut and Linden streets.

The dip of the strata, where the limestone outcrops, is toward the south. All the specimens of fossils obtained from this stratum were very much stained with oxide of iron.

When the lock of the Mill Creek Slack Water Navigation, on the south side of the creek and immediately opposite this limestone outcrop, was built, about 1865, a num-

12 PINNA PERACUTA.

ber of fossils were obtained from the excavations made in the calcareous black slate at the foot of the lock.

The Mill Creek limestone outcrops again along the fence of the Hollenback Cemetery, facing the Susquehanna river on the west side of Mill creek, about 65 feet south of the Lehigh Valley railroad track.

On the road between Kingston and Plymouth, and about half a mile north-east of the Boston breaker, an outcrop of limestone occurs which is 2 feet thick. This outcrop Mr. Schaarer believes to be on the Mill Creek limestone.

As nearly as can be made out, the Mill Creek limestone occurs between 30 and 40 feet beneath the Joe Gibbs coal-bed. This coal-bed outcrops on either side of River street on both the Hollenback Cemetery bank and the Hospital bank, and near the end of Linden street. The dip of the bed is east of north from the Cemetery anticlinal, into and toward the Cemetery basin. (See Mine Sheet No. VIII, Atlas Northern Anthracite Field, Part I.)

In the Dorrance shaft, a little over a quarter of a mile south-west of this outcrop, what has been taken for the Joe Gibbs coal-bed was cut in the shaft at a depth of 130 feet 7 inches. The dip of the strata in the Dorrance shaft, from the top of the shaft down to the coal-bed, ranges from 39 to 37 degrees in a direction south. Although, at the time that the section of the Dorrance shaft was measured by Mr. Frank A. Hill, Assistant Geologist, the *representative* of the Mill Creek limestone was not noticed, it would, upon close examination, probably be found in the shaft at a depth of about 170 feet.

On the south-east bank of the canal, 800 feet south-west of the mouth of Mill creek, and near the line separating the Hollenback and the Public Cemeteries, occurs an outcrop of a siliceous non-fossiliferous limestone much softer than the Mill Creek limestone. This bed I have named the Canal limestone, and it occurs about 30 feet stratigraphically below the Mill Creek bed. The Canal limestone is 2± feet thick.

Seventy feet south-west of this limestone outcrop occurs an interesting outcrop of dark gray slate, the top of which

is about 10 feet below the Canal limestone-bed. Immediately after the original deposition, in the water-basin of the Carboniferous age, of the mud and silt which ultimately formed this slate bed, the mud and silt were washed away either by a current in the depositing waters or by a stream which flowed over the mud bed. In the latter case, the level of the water, which existed during the time that the mud and silt were deposited, must have been considerably lowered, by the water being withdrawn in order to permit of the formation of a creek bed. This *ancient cut* was subsequently filled with sand and mud, which replaced the mud and silt which had been washed away.

The Canal limestone-bed was cut in the Dorrance shaft, and pieces of limestone could quite recently be found in the rock dump in the vicinity of the shaft. The slate, passed through by the shaft, between a depth of 207 feet 6 inches and 223 feet 6 inches, is, without doubt, the representative of the slate found along the river bank, below the Canal limestone. An outcrop of the Mill Creek limestone was found by Mr. Schaarer west of the dirt dump at the engine house, near the foot of the Dorrance breaker plane, and about midway between the Dorrance shaft and the Dorrance breaker. About 25 feet stratigraphically above the limestone outcrop, an outcrop of the Joe Gibbs coal-bed is reported to have been found, the coal-bed being apparently about 1 foot thick.

About 10 feet above the top of the Conyngham shaft a limestone-bed was cut in an adjoining ditch. This limestone-bed is, without doubt, the representative of the Canal limestone.

On Main street north-east of Elk street, and very nearly on the line between the Conyngham and Prospect shafts, occurs an outcrop of the Mill Creek limestone, having a dip of 85 degrees due south. The outcrop is located on the crest of the Cemetery anticlinal, and a number of fossils were obtained from the limestone at this point.

About 150 feet nearly north-east from this latter outcrop, and on the top of a small hill, the Mill Creek limestone outcrops on the north dip. This was the point from which

Judge Mallory's farmer got most of the lime which was burnt.

The Mill Creek limestone is exposed on the west side of the river, between the Mill Creek bridge and the bridge over the railroad at the foot of the Prospect culm-bank. The limestone is also exposed in the Lehigh Valley railroad cut west of the Prospect breaker.

In this railroad cut the Canal limestone is exposed. Ninety feet below the Canal limestone at this point the River coal-bed, which is the representative of the Rock bed struck in the Dorrance shaft at a depth of 325 feet 9 inches, occurs. Twenty-five feet stratigraphically below this coal-bed occurs a third limestone.

In addition to these three limestone beds two others are reported, but I did not find their outcrops.

In the Dundee shaft on the south side of the Susquehanna river about a mile and a half east of Nanticoke, fossils were obtained in a black slate statum extending from a depth of 281 feet 3 inches to 314 feet 9 inches. The exact position of this slate-bed in the Coal Measures is not known, since the Dundee shaft section has never been satisfactorily compared with other sections. Mr. Hill is disposed to believe that the Dundee fossiliferous slate is about 600 feet above the Hillman coal-bed.

In a cut on the Lehigh Valley railroad south-west of the Hillman Colliery breaker there is exposed 2 feet of a tough siliceous limestone which occurs 10 feet above the Hillman coal-bed. This latter limestone has been by some considered to be the same as the Mill Creek limestone-bed ; there is, however, nearly 500 feet of strata between the two limestones. No fossils have been found in the Hillman limestone.

The relative positions of these limestone-beds in a general section of the Coal Measures of the Wyoming valley is shown in the following section, compiled from the Dorrance shaft, down to the bottom of the Rock coal-bed ; from thence from the Conyngham shaft section down to the bottom of the Baltimore coal-bed ; from thence from the record of the Baltimore bore-hole, down to the Red Ash coal-

bed, and from thence, from the Red Ash bore-hole, to the bottom of the section:

	Feet.	Inches.
1. Slate,	51	5
2. *Coal* and dirt,	2	10
3. Slate,	7	2
4. Sandstones, soft,	2	1
5. Slate,	21	1
6. Sandstone,	5	5
7. Slate,	3	4
8. Sandstone, hard,	11	1
9. Slate,	1	10
10. *Joe Gibbs coal-bed,*	1	10
11. Sandstone,	30	0
12. MILL CREEK LIMESTONE,	1	0
13. Sandstone,	25	0
14. CANAL LIMESTONE,	2	0
15. Slate,	14	0
16. *Coal,*	1	10
17. Sandstone,	11	0
18. Slate and sandstone,	7	5
19. Sandstone,	13	1
20. Slate and fire-clay,*	2	2
21. Sandstone,	39	4
22. Slate,	7	6
23. *Rock, or K coal-bed,*	7	2
24. Slate,	3	2
25. *Coal,*	2	6
26. Slate and sandstone,	25	0
27. LIMESTONE,	2±	
28. Conglomerate, sandstone, and slate,	33	0
29. *Abbott, 7-foot, or J coal-bed,*	5	0
30. Sandstone,	51	0
31. Conglomerate,	10	0
32. Sandstone,	15	0
33. *Bowkley, or I coal-bed,*	5	0
34. Slate,	17	0
35. Conglomerate,	20±	
36. HILLMAN LIMESTONE,	3	0
37. Slate,	10	0
38. *Hillman, or H coal-bed,*	16	0
39. Conglomerate and sandstone,	150	0
40. *G coal-bed,*	3	0
41. Sandstone,	57	0
42. *5-Foot, or F coal-bed,*	3	0
43. Fire-clay,	12	0
44. Sandstone,	116	0

*This stratum is probably calcareous, and may in some cases be the limestone bed representative of one of the limestone beds whose outcrop I did not find.

	Feet.	Inches.
45. *Baltimore, E, or Mammoth coal-bed,*	16	0
46. Sandstone,	106	0
47. *Coal-bed,*	2	0
48. Sandstone,	26	0
49. *Coal-bed,*	1	0
50. Sandstone,	87	0
51. *Coal-bed D,*	4	0
52. Slate,	6	0
53. *Coal-bed,*	1	0
54. Slate,	21	0
55. *Ross, or C coal-bed,*	7	0
56. Sandstone,	28	0
57. *Red Ash, or B coal-bed,*	17	0
58. Slate,	2	0
59. *Coal-bed A,*	2	0
60. Slate and sandstone,	11	0
61. Conglomerate, Pottsville, No. XII,	96	0
62. Mauch Chunk red shale, No. XI.		
Total thickness of measures,	1267	0

Part II.

Although some doubt has been entertained by certain geologists and palæontologists as to the age of the deposits represented by the fossils in question, whether Upper Carboniferous or Permian, there is, in my opinion, not the remotest foundation for the existence of such doubt. Apart from all stratigraphical evidence, which appears to be absolutely confirmatory of the evidence presented by palæontology, we have, in the numerous and varied organic remains, the most indisputable demonstration of the Carboniferous formation. By far the greater number of the fossils—not impossibly all of them—have already been described from the equivalent, or nearly equivalent deposits of the States west of Pennsylvania, concerning whose age there appears to be on question. But even if there were such a question in some instances, it would not affect the present issue, since the Wilkes Barre fossils unequivocally represent Carboniferous species. Not a single distinctively Permian fossil occurs in the collection, although the Schizodus forms may perhaps with propriety be considered to represent as well a newer as an older horizon. The fragments of Trilobites

(Phillipsia) are in themselves sufficient to dispel any doubt that might arise as to the stratigraphy of the region. inasmuch as we know of no members of this group of organisms surviving the coal period, unless they be the forms described by Shumard from the very doubtfully placed Permian deposits of the Sierra Madre. At the same time, it is by no means impossible, or even very improbable, that indisputable Permian Trilobites may yet be discovered.

These fossils occur in a very ferruginous, earthy limestone, of a rusty yellow color, and are mainly in the nature of casts and impressions. They are the property of the Wyoming Historical and Geological Society of Wilkes Barre, and of Mr. Chris. H. Scharar of Scranton, through whose kindness they have been placed in the hands of the Geological Survey for examination. In addition to these a number of other fossils from the black shales of the same region were sent on by the Wilkes Barre Society for determination. The species of the latter specimens are, in most cases, only doubtfully determined. They are:

Modiola minor, Lea.
Modiomorpha sp. ? (near to *M. alta*, Conrad.)
Modiomorpha sp. ? (near to *M. complanata*, Hall.)
? Edmondia Burlingtonensis, White.
Palæoneilo Bedfordensis, Meek.
Aviculopecten, sp. ?
Pterinopecten, sp. ?
Grammysia Hamiltonensis, Shumard.
Grammysia, sp. ? Fig. 8.
Schizodus, (near to *S. quadrangularis*, Hall.)
Schizodus, sp. ?
Solenomya anodontoides, Meek.
Platyceras acutirostris, Hall.
Bellerophon percarinatus, Conrad.
? Bellerophon sublævis, Hall.

From the Upper Coal Measures.

The following list comprises most of the fossils from the Mill Creek limestone bed:

BRACHIOPODA.

Discina.

Discina convexa, Shumard. (Fig. 18.) Trans. St. Louis Acad., I, p. 221, (1858.) White, Geol. Rept. Indiana, 1883, p. 121, pl. 25, Fig. 9. Two impressions of *Discinæ* occur in the rock, one of which is unmistakably referable to the above species. It measures about an inch in basal diameter, and somewhat more than a third of an inch in the apical height of the convex valve. The concentric lines are well indicated. The impression of the second specimen is not as clearly defined, and may possibly represent *Discina Newberryi*, which, however, does not appear to differ much, if at all, from *D. convexa.*

18. DISCINA CONVEXA.

Chonetes.

Chonetes (?) *millepunctata*, Meek and Worthen, (Fig. 3.) Meek and Worthen, Proc. Ac. Nat. Sci., Phila., 1870, p. 35.

Meek and Worthen, Geol. Surv. Illinois, V, p. 566, pl. 25, Fig. 3.

Several determinable impressions of this remarkable brachiopod, one of which, measuring two and a half inches across, would indicate in the perfect specimen an expanse of about four inches.

Punctæ very fine and exceedingly numerous.

Productus.

Productus Cora, D'Orbigny, (Figs. 1 and 1a.)

White, Geol. Rept. Indiana, 1883, p. 126, pl. 26, Figs. 1, 2, and 3.

This species is represented by a large fragment, (upper moiety of valve,) and by a nearly perfect convex or vertical valve, in which the distinctive characters of the species—the fine longitudinal lines, without medial impression, and broad corrugated auriculation—are clearly exhibited. Umbonal height somewhat more than two inches.

Productus Nebrascensis? Owen, (Figs. 4, 4a, 4b, and 4c.)

Owen Geol. Rept. Wis., Iowa, and Minn., p. 584, pl. V, Fig. 3.

White Geol. Rept. Indiana, p. 122, pl. 24, Figs. 7, 8, and 9.

4c PRODUCTUS NEBRASCENSIS?

There are several fairly well preserved specimens of a very convex and strongly scrabiculate *Productus*, whose nearest relationship among American forms appears to be with *P. Nebrascensis.* It seems to differ from this species, however, in the more prominent pustulation of the dorsal valve, a character in which it agrees more nearly with the common European *P. pustulosus* (Phillips.) This one distinctive feature is probably of no more than varietal importance, and I accordingly prefer to place the species under *P. Nebrascensis.*

Athyris.

Athyris subquadrata,? Hall, (Fig. 2.).

Hall, Iowa Rept., vol. 1, part 2, p. 703, pl. XXVII, Fig. 2.

Several more or less perfect casts.

Spirifer.

Spirifer lineatus? Martin, very doubtful.

ACEPHALA.

Aviculopecten.

Aviculopecten Winchelli, Meek, (Figs. 6, 6a, and 6b.)

Meek. Ohio Geol. Rept. II, p. 296, pl. 15, Fig. 5.

Two or more less perfect impressions.

[illegible] AVICULOPECTEN WINCHELLI.

19a PINNA PERACUTA.

Aviculopecten occidentalis, Shumard, (Figs. 5 and 5a.)

Shumard, 1855, Swallow's Geol. Rept. Missouri, p. 207, pl. C, Fig. 18.

White Geol. Rept. Indiana, 1883, p. 143, pl. 28, Fig. 3.

Eumicrotis.

Eumicrotis Hawni, Meek and Hayden.

5a AVICULOPECTEN OCCIDENTALIS.

Trans. Albany Inst., IV, (1858.)

Meek and Worthen, Geol. Surv., Ill., II, p. 338, pl. 27, Figs. 12, 13, and 14.

An obscure impression which may be that of this species, but very doubtful.

Monopteria.

Monopteria (*Pterinea*) *gibbosa*, Meek and Worthen, (Figs. 11 and 11a.)

Meek and Worthen, Proc. Chicago Acad. Nat. Sci., 1866, p. 20.

Meek and Worthen, Geol. Surv. Ill., II, p. 340, pl. 27, Fig. 11.

White, Geol. Rep. Indiana, 1883, p. 139, pl. 30. Figs. 11 and 12.

11a MONOPTERIA GIBBOSA.

One specimen, which very clearly exhibits the distinctive features of the species. The species appears to be very intimately related to *Monopteria auricula* of Stevens (Am. Journ. Science XXV, p. 265,) and to *Gervillia longispina*, Cox, (Kentucky Rept. III, p. 568.)

Pinna.

Pinna peracuta, Shumard. (Figs. 12 and 12a.)

Shumard, Trans. St. Louis Acad., I, p. 214, (1858.)

White, Geol. Rept. Indiana, 1883, p. 145, pl. 28, Figs. 1 and 2.

Several impressions and casts, one of the latter fragments measuring five inches in length, and two and a half in greatest width.

Myalina.

Myalina subquadrata, Shumard. (Figs. 15 and 15a.) Swallow, Geol. Surv. Missouri, p. 207, pl. C, Fig. 17. Several fragmentary casts and impressions.

Macrodon.

Macrodon obsoletus, Meek. (Fig. 19.)

Meek. Rept. Regents' Univ. W. Virginia, 1871.

Meek, Ohio Rept. Palæontology II, p. 334, pl. 19, Fig. 9.

Schizodus.

Schizodus cuneatus? Meek. (Figs. 9 and 9a.)

19 MACRODON OBSOLETUS.

Meek, Ohio Rept. Palæontology II, p. 336, pl. 20, Fig. 7.

A cast of a large *Schizodus*, measuring two inches in length, may possibly belong to this species; the absolute specific determination is somewhat doubtful, however.

Schizodus Wheeleri, Swallow. (Fig. 7.)

Swallow, Trans. St. Louis Acad. II, p. 96. (1862.)

9a SCHIZODUS CUNEATUS.

White, Geol. Rept. Indiana, 1883, pl. 30, Figs. 3, 4, and 5.

Several nearly perfect casts.*

10a ALLORISMA SUBCUNEATA.

* Fig. 7a (Plate, page 446), intended for a Bellerophon, is incorrectly referred to this species.

Allorisma.

Allorisma subcuneata, Meek and Hayden, Fig. 10 and 10a.

Meek and Hayden, Pal. Upper Missouri, 1864, p. 37, pl. 1, Fig. 10.

White, Geol. Rept. Indiana, 1883, p. 148, pl. 31, Figs. 1, 2, and 3.

Grammysia.

Undetermined casts and impressions.

GASTEROPODA.

Macrocheilus.

Macrocheilus primigenius, Conrad, (Figs. 16 and 16a.)

Conrad, Trans. Geol. Soc. Pennsyl., 1835, p. 267, pl. 12, Fig. 2.

Conrad, Iowa Rept., 1, 720.

One fairly defined cast.

Bellerophon ?

Bellerophon nodocarinatus, Hall, (Fig. 13.)

Hall, Iowa Rept., part II, p. 723, pl. XXIX, Fig. 15, a, b, and c.

13 BELLEROPHON NODOCARINATUS?

Bellerophon crassus (*var.*)? Meek and Hayden.

Meek and Hayden, Proc. Ac. Nat. Sci., Phila., 1860, p. 458.

The identification of both of these specimens is somewhat doubtful.

CEPHALOPODA.

Nautilus, *sp.?*

Orthoceras, *sp.?*

Both genera represented by several ill-defined casts and impressions.

TRILOBITA.

Phillipsia.

Phillipsia Sangamoensis, Meek and Worthen, (Figs. 14 and 14a.)

Meek and Worthen, Proc. Ac. Nat. Sci., Phila., 1865, p. 271.

14a PHILLIPSIA SANGAMOENSIS

Meek and Worthen, Geol. Surv. Illinois, V, p. 615, pl. 32, Fig. 4.

Represented by two pygidia.

CHAPTER XI.

Report on the Bernice Coal-basin in the Loyalsock and Mehoopany Coal-field, in Sullivan County.

By CHARLES A. ASHBURNER.

General Description.

The Loyalsock and Mehoopany Coal-field extends through parts of Sullivan and Wyoming counties, and has been called by various names.* It lies back of and to the north, of what may be considered the most north-eastern extension of the Allegheny mountains. The general name, North mountain, has been assigned to that portion of the Allegheny mountain between Muncy creek, in eastern Lycoming county, and Bowman's creek, in south central Wyoming county. Local names have been assigned to different parts of this mountain; that part lying to the south of the West Branch of Fishing creek, in Davidson township, Sullivan county, and Jackson and Sugar Loaf townships, in Columbia county, being known as Bald mountain; that part between the main branch of Fishing creek and Kitchen creek, in Sugar Loaf township, Columbia county, and Fairmount township, Luzerne county, being specially known as North mountain. To the east of Bowman's creek the summits become much lower, that between this creek and the Susquehanna river being known as Bowman's mountain and Eaton knob; that on the east side of the Susquehanna river, and between it and the south branch of Tunkhannock creek, being called Tunkhannock mountain, while the summit be-

*On the page plate map of the Anthracite region accompanying this report, this coal-field has been designated the Western Northern in contradistinction to the Northern, Eastern Middle, Western Middle, and Southern anthracite fields.

tween the main and south branches of Tunkhannock creek is known as Elk mountain.*

Back, and to the north of this mountain frontier, the strata are comparatively horizontal, possessing the low dips which are universally found all through the State back of the Allegheny crest; the Coal Measures are only found existing on the higher summits, which are the only remaining portions of the original plateau, which, in later geological times, has been broken up into a region having a rugged topography, the valleys having been cut out by the natural erosion of the strata; the resulting *debris* having been carried away by the streams.

The accompanying page plate map, on a scale of four miles to an inch, exhibits the principal areas where the Coal Measures, carrying coal-beds in this field, are still to be found. Special names have been assigned to the individual patches of coal measures, which names, in certain communities, have been used to some extent to designate the greater or entire portion of this coal-field. That portion of the field in Wyoming county is more generally described as the Mehoopany, since the Mehoopany creek and its branches drain the largest portion of its area, while that section of the field in Sullivan county, which is drained by the Big Loyalsock creek and its branches, has been generally known as the Loyalsock Coal-field.

The principal coal area in Sullivan county exists in the immediate vicinity of Bernice, and is almost exclusively the property of the State Line and Sullivan R. R. Co. The smaller part of the area being owned by the heirs of the Jackson Estate. This special district is frequently spoken of as the Loyalsock; sometimes as the Bernice, since the mining village of Bernice, on account of the important mining which has been carried on in its immediate vicinity, is better known than any other town in the county.

---

*In the south-eastern corner of Susquehanna county, the high summits which are such prominent features of the topography of this part of the State, on one of which has been established a triangulation station of the U. S. Coast and Geodetic Survey, are also known as the Elk mountains; they might be more correctly called the Elk knobs. North Elk knob has an elevation above tide of 2700 feet, and South Elk knob, one mile away, an elevation of 2575 feet, (Report G^6, p. 186.)

In 1878 Mr. Franklin Platt, late Assistant Geologist of the Survey, made a general examination of this coal-field and also of the coal areas in Lycoming county, and his report has been published with considerable detail in Report GG, which relates to the geology of Lycoming and Sullivan counties. At the time that the earlier examination was undertaken, no accurate surveys had been made of the Bernice coal-basin, and since Mr. Platt had no opportunity then to make such instrumental surveys, his examination was necessarily incomplete. In that portion of the field in Wyoming county a greater want has always existed for some map of the region than even in Sullivan county.

During the past three years, both before and since the State Line and Sullivan R. R. passed intothe Lehigh Valley R. R. Co.'s hands under lease, this latter company made extensive surveys between the terminus of the State Line and Sullivan R..R., at Bernice, and prominent points on the Susquehanna river, between Tunkhannock, in Wyoming county, and Shickshinny, in Luzerne county. These surveys have been directed by Mr. A. W. Stedman, Chief Engineer of the Lehigh Valley R. R., and have been under the immediate charge of Mr. J. Benton Brown, Assistant Engineer. The maps and notes of these surveys have been placed at the disposal of the Geological Survey.

In the spring of 1883 a special examination of the Loyalsock and Mehoopany field was planned which should show the local geological structure of the coal-basins and their connection with the south-western end of the Northern Coal-field, by maps and sections. The consummation of this plan was prevented by the exhaustion of the funds of the Survey, a subsequent restricted appropriation and consequent reduction in the size of the field corps.

Topographical Map.

An offer was made on the part of the State Line and Sullivan R. R. Co., to put a topographical corps in the field, under the direction of the Geological Survey, and construct a contour curve map of that portion of the Bernice coal-basin, situated on their property if the Survey would under-

take to extend the map beyond the company's tract, to include the topography of the whole basin, publishing the combined maps with such geological notes as might be made during the progress of the work. This proposition was accepted, and a survey of the property of the State Line and Sullivan R. R. Co. was made by Mr. P. E. Alden; subsequently Mr. E. B. Harden, under my direction, and aided at different times by Messrs. Griffith, Halberstadt, and Clarence R. Claghorn, extended the map to include all the coal areas adjoining the company's property.

After the completion of the topographical map, I made a personal examination of the geology of the entire area embraced by it, in company with Messrs. Alden and Claghorn, in July, 1884, and from these observations the geology contained on the topographical map accompanying this report was outlined.

The outcrop of the bottom of coal-bed B, (so called,) which is the bed being mined by the company, and a portion of the outcrop of the underlying coal-bed A, together with portions of the outcrop of the bottom of the Pottsville Conglomerate, No. XII, as defined on this map, could only be approximately determined on account of the very few exposures and the limited explorations which had been made, beyond the areas actually exploited by the company's mines. These geological lines are, however, as accurately located on the map as has been possible without opening additional drifts along the outcrop of the coal-beds, by sinking additional shafts, and by boring additional drill-holes. West of a north and south line drawn through Drift No. 6 on this map, the limits assigned to these two geological horizons were determined with more certainty than those east of the same line since coal-bed B within the former area has been extensively worked and explored by the company, and the area which it underlies and the depth of the bed below the surface are known with certainty.

The dip of the coal measures in some of the areas covered by the map coincide so nearly with the slope of the surface of the ground that it has been impossible with any degree of accuracy to geometrically construct the approxi-

mate out-crops of the coal-beds or conglomerate, where but few exposures were found and almost no explorations had been made. This would apply particularly to the area referred to east of a north and south line through Drift No. 6. Within the area of the main portion of the basin the darkest tint on the map represents the area underlaid by bed B, or the bed which is at present being mined; the next lighter shade represents the area underlaid by bed A, as nearly as could be determined.

In the northern part of the map, where bed A and bed B do not exist, but where the outcrop of the top of the Mauch Chunk Red Shale, No. XI, is to be found, the lighter shade extends down to the top of No. XI or the bottom of the Pottsville Conglomerate, No. XII. This explanation is not needed for a practical appreciation of the accompanying map, but is made for the use of geologists who may examine the areas which are included on the map and which are of no commercial value for coal.

Elevations.

*The following is a list of the elevations, above tide, of prominent points in the Bernice coal-basin:**

	Feet.
Junction of Loyalsock and Birch creeks,	1500
Meylert opening on coal-bed A,	1881
B. M. at S. E. corner company's property on Loyalsock creek,	1618
Top of air-shaft near old Jackson drift,	1866
Mouth of old Jackson drift,	1939
Opening on coal-bed A, near old Jackson drift,	1876
Drift No. 4,	1908
Drift No. 1,	1881
N. W. corner company's property at No. 5 opening,	1930
Road at Shinersville school-house,	2047
Bernice, (junction of wagon roads near store,)	1899
Schaad's hotel,	1835
No. 6 drift, (east of turnpike,)	1877
Ackley's saw mill, (water,)	1850

*The original levels run by Mr. P. E. Alden were based upon an assumed datum plane 98.5 above tide, so that to all the elevations noted on Alden's orginal map, 98.5 feet have been added, to reduce the same to the tide-water datum of the Lehigh Valley Railroad.

	Feet.
Shaft on bottom bench Coal-bed B, near Ackley's saw mill,	1911
" middle " " " " " "	1938
Eight-foot opening, (top of coal-bed,)	1902
Heiss opening, (top of coal-bed,)	2036
P. Caugley's house,	2031
Stroud's saw mill,	2067
Tamarack swamp,	1937
Top of bore-hole on turnpike,	1910
Top of air-shaft south of Bernice, (22 feet to coal-bed,)	1932

Bernice Mines.

The mines of the State Line and Sullivan R. R. Co. have been driven exclusively in Coal-bed B, which, as is shown in the sections of the coal measures referred to later, is about 60 feet above Coal-bed A, the latter being geologically the lowest coal-bed which has been found in the coal measures of the basin. The mines are situated immediately to the south and west of Bernice village, and lie in two prominent and independent areas. The mines in the western area, which is partly on the mining company's tract and partly on the tract of the Jackson estate, are generally spoken of as the Jackson mines. All the coal which has recently been mined from this area has been brought out of Drift No. 4.

The larger area lies exclusively on the property of the company and immediately south of the Bernice breaker. All the coal which has recently been mined from the latter area has been brought out of Drift No. 3, the nearest opening to the breaker.

Drifts Nos. 1 and 2 are connected with this latter area. On the larger scale mine map* the areas which are worked, in both the bottom and top benches of the bed, are shown by distinctive shadings in each case. This map was brought up to the stage of the developments which had been made prior to February, 1884. A recent examination made of

*A plan of the mines is shown with great minuteness on the topographical map of the Loyalsock basin, contained in the Atlas accompanying this report. The mines are represented on two independent scales; first, on a scale of 800 feet to one inch, and second, on a scale of 1600 feet to one inch. The latter representation is placed in its proper relation to the surrounding areas on the topographical map.

the mine maps, brought up to November, 1885, showed that very little working had been done beyond the limits of the published map, most of the coal during the past two years having been mined inside of the limits of the mapped area.

The Bernice coal being much softer than most of the free-burning white ash anthracites, the coal is broken by machinery which is peculiar to the Bernice breaker.

"In the breaker a massive plate, fitted with iron teeth, takes the place of the crushers. This plate in descending strikes the coal lumps, and, taking advantage of the tendency of the coal towards a partial cubical structure, easily splits the lumps into pieces of varying size, and practically turns out about the same proportion of the various sizes of coal as the average at collieries in the anthracite regions."*

The capacity of this breaker is about 100,000 tons. During the past three years the shipments of coal from the breaker have been as follows: 1883, 84,376 tons; 1884, 84,551 tons; 1885, 73,117 tons.

Description of Coal-bed A.

The only areas in the Bernice basin commercially valuable for mining purposes are those underlaid by coal-bed B. Developments made in coal-bed A give no promise of a workable bed.

The Meylert opening, near the western end of the basin, is on coal-bed A. This opening had fallen shut when visited, but the bed is reported to have been found two feet thick.

In February, 1886, the Meylert drift was re-opened by Mr. C. R. Claghorn, Assistant Superintendent of the mines of the S. L. & S. R. R. Co. His report is as follows: "The coal is bright, shining, and hard, and makes a very good showing. I doubt, from the condition I found the drift in, that any one has been to the face for a number of years to obtain specimens for analysis. I measured the following sections, showing the slight thickening of the coal from the outcrop:

*Report GG, page 183.

No. 1, 12′ from drift mouth.

Sandstone,	?
Slate roof,	?
Coal,	3″
Slate and bone,	9″
Coal,	9″
Bone,	8″
Slate,	bottom.
Total coal,	1′

No. 2, at face, 150′ from mouth.

Sandstone,	?
Slate roof,	?
Coal,	3″
Slate and bone,	6″
Coal,	11″
Bone,	8″
Slate,	bottom.
Total,	1′ 2″*

A number of large lumps were taken from the bed at the face of the drift, and analyzed by Messrs. Salom and Westesson, with the following results:

Moisture,	1.43
Volatile matter,	10.17
Fixed carbon,	85.72
Ash,	2.68
	100.00
Sulphur,	0.12
Carbon ratio,	1 : 8.4

In the run, 45 feet below the Meylert opening, there is an outcrop of red shale, evidently the top of the Mauch Chunk Red Shale formation, No. XI. It is estimated that there is at least 40 feet of sandstone and conglomerate under the coal-bed A at this point, representative of the lower part of the Pottsville Conglomerate, No. XII. Below the opening on coal-bed A, in the vicinity of the Old Jackson drift, there is probaby 40 or 50 feet of sandstone and conglomerate representing the same stratum.

The only other point in the Bernice basin where coal-bed A has been certainly opened is at the Heiss opening, nearly two miles north-east of Bernice. The coal-bed at this point

*If the bottom "bone" should be included in the bottom coal-bench, the bed might be called a two-foot bed.

varies from 10 inches to 2 feet thick, is very much faulted, and the rocks overlying it are false-bedded.

The following is a section compiled from observations taken in the Jackson air-shaft, between the old Jackson drift, Mine No. 5, and opening on coal-bed A, and shows the relationship of bed A to bed B.

1. Soil,		6′	0″
2. Gray, micaceous, shaly sandstone,		6′	3″
3. Gray slaty shale,		2′	0″
4–11. *Coal-bed B.*	4. *Coal*, top bench,	4′	0″
	5. Slate and bony coal,	0′	9″
	6. *Coal*, middle bench,	1′	2″
	7. Slate and bony coal,	1′	3″
	8. *Coal*,	0′	4″
	9. Sandy slate,	0′	3″
	10. *Coal*, bottom bench,	3′	10″
	11. Fire-clay,	4′+	
12. Interval,		5′	0″
13. Sandstone and conglomerate,		45′	0″
14. Black slate,		6′	0″
15. *Coal-bed A*,		1′	11″
16. Slate,		0′	3″
17. Fire-clay,		7–8′	0″
18. Hard sandstone,		22′	0″
19. Conglomerate and sandstone,		30′	0″
Total,		148′	0″

Prior to the control of the Bernice coal property by the present company, a bore-hole was sunk from the floor of bed B in mine No. 4, about 300 feet from the outcrop, to the estimated level of bed A, in order to determine whether bed A existed with workable dimensions. The strata passed through in this hole were reported to be as follows:

1. Fire-clay (floor of bed B,)	15′
2. Drab rock, very hard,	10′
3. Hard sandstone,	20′
4. Fire-clay,	5′
5. Slate,	4′
6. Dark slate and coal,	10′
7. Sandstone, (bore-hole stopped in this sandstone,)	—
Total,	64′

Mr. Platt, in referring to this record, says:

"There were not 6 inches of coal in all the dark slate and clay which occupy the horizon of the lower coal-bed. It

may be that the bore-hole has passed through only a wash-out of the lower coal, which would prove small and have the bed on all sides in good order; but there is so much irregularity in these measures in the Bernice basin as to prevent any great hopefulness for improvement or persistency."

All the information it is possible to obtain bearing upon the probable existence of bed A with a thickness sufficiently great to make it profitable to mine, points to the conclusion that very little hope can ever be entertained of the coal-bed being found in such a favorable condition. Two specimens of coal-bed A were collected from the prospecting drift in this bed, below the old Jackson drift, one in 1877 and one in 1884. Analyses of both of these specimens were made by Mr. McCreath. They are as follows:

	1.	2.
Water,	4.130	3.670
Volatile matter,	15.270	15.420
Fixed carbon,	67.362	71.341
Sulphur,	.523	.594
Ash,	12.715	8.975
	100.000	100.000
Color of ash,	reddish gray.	cream.
Carbon ratio,	1: 4.4	1: 4.6

Specimen No. 1 was collected by Mr. Platt in 1877, and specimen No. 2 by myself in 1884, analysis of the latter being made in November, 1885. Although the amount of ash contained in the analysis of the first specimen collected is considerably more than that contained in the second, the analyses in other respects are very similar. The difference in the ash is readily accounted for. Subsequent to 1878, when the first specimen was collected, the opening, from which these coals were collected, was driven several feet further in the hill, and specimen No. 2 was obtained further from the outcrop than specimen No. 1, and, therefore, the coal was more solid and cleaner. Mr. McCreath, in making special reference to his examination of specimen No. 1, says:

"The coal does not yield a coke and the gases burn with a *very feebly* luminous flame.

"The coal after being dried begins to absorb water rapidly, and in two hours has re-absorbed about 60 per cent. of the water originally present. This amount is not increased by longer exposure.

"On drying, at 225° F., the coal loses,	4.13
at 245° F., the loss is the same.	
at 260° F., the loss is	4.19
at 340° F., the loss is	4.69
at a dull red heat the loss is	12.59

"But, in all these experiments, the water re-absorbed is about the same; that is, the coal re-absorbs about 2.48 parts of water.

"Irrespective, therefore, of the amount of water, &c., driven off by heat, the portion re-absorbed is practically constant, and this property is not destroyed even after all the volatile matter has been driven off."

These analyses are of no practical value, since the bed from which they have been obtained cannot be profitably mined, but they are of great interest, (1,) in proving the existence of a bituminous coal-bed underlying the bed which is mined, which is a semi-anthracite, in accordance with the classification which has already been referred to in this report; and (2,) in showing a remarkable peculiarity which the coal possesses of re-absorbing water after it has been once driven off.

The analysis of the sample from coal-bed A, which was obtained from the Meylert opening by Mr. C. R. Claghorn, already referred to, shows quite a different composition for bed A at this point than at the Jackson opening. The Meylert sample shows 85.72 per cent. of fixed carbon and only 10.17 of volatile matter, the carbon ratio of the coal being 8.4 under the classification referred to in this report. (See page 301.)

The Meylert coal is a semi-anthracite, or, according to the trade classification, would have to be called a true anthracite.

In the two samples of coal collected from the Jackson opening, of which analyses are given above, the carbon ratio is practically the same, being 4.4 in one case and 4.6 in

the other case; the fact that the first sample contains as much as 13 per cent. of ash and the second only about 9 per cent., has nothing to do with the classification of the coal, since the ash in all methods of chemical classification based upon composition is considered an accidental impurity. The difference between the Meylert coal and the Jackson coal, however, proves very decidedly one fact; that is, that the coal contained in bed A is of variable composition, the carbon ratio being greater at one locality than at another. This is not an unusual occurrence, since explorations conducted not only in the Pennsylvania coal-fields, but in foreign fields, have shown that no one coal-bed can be expected to have a fixed composition as far as the relative proportions of fixed and volatile hydro-carbons are concerned, although, in some instances, a coal-bed may have an unchangeable composition over a greater area than in other cases. In the case of bed A, in the Bernice field, the carbon ratio in a distance of less than a mile and a half is found to change from 4.4 to 8.4.

Description of Coal-bed B.

The principal economic interest which is attached to this portion of the Loyalsock field is the existence here of a valuable workable semi-anthracite coal-bed. The bed occurs under geological conditions similar to those which generally obtain throughout the bituminous regions of the State, but the coal has a composition which of itself would entitle it to rank higher in the trade than some of the softer coals mined from the anthracite region proper; yet the Bernice coal has the physical properties and structure of many of the Pennsylvania bituminous beds, and is itself underlaid by a bituminous bed. This anthracite bed has been explored and extensively mined in the vicinity of Bernice. The area under which this coal-bed is supposed to lay is shown by the darkest shade on the accompanying map, (see Atlas of Annual Report,) and the area of the bed which is worked is shown by a map of the mine placed in its proper position relative to the surrounding topographical features.

There seems to be but little doubt that the Bernice coal-

beds are the true geological representatives of the Lykens Valley coal-beds which are found in the Pottsville Conglomerate No. XII, generally throughout the anthracite region, but which are most favorably known from their occurrence in the Lykens Valley district,* at the western end of the Southern anthracite field, where they are found with their maximum thickness and purity and have been extensively mined. The identity of the Bernice beds with the Lykens Valley beds is a matter of more importance to geologists than to the coal trade and coal consumers, since, in a distance of 55 miles between the Lykens Valley and Bernice coal-fields, it would be more natural for the coals to have changed their characters as far as their value as a fuel is concerned than that their characteristics in this respect should remain the same.

In the main gangway of the old Jackson mine, 200 feet west from the property line separating the Jackson estate from the property of the State Line and Sullivan Railroad Company, the following section was measured of Bed B:

Sandstone roof.		
Coal, top bench,	3′	4″
Bony coal and slate,	0′	8″
Coal, middle bench,	1′	4″
Slate and bony coal,	1′	0″
Coal,	0′	5″
Sandy slate,	0′	5″
Coal, bottom bench,	4′	0″
Fire-clay floor.		
Total coal,	9′	1″

The bottom bench, which is 4 feet thick in the above section, has a thickness of 5 feet about 300 feet west of where this section was measured.

Near the Jackson air shaft the following section of bed B was measured:

Gray slaty shale roof,	2′	0″
Coal, top bench,	4′	0″
Slate and coal,	0′	9″
Coal, middle bench,	1′	2″
Slate and bony coal,	1′	3′

*The Lykens Valley district includes the Brookside colliery.

Coal,	0′ 4″
Sandy slate,	0′ 8″
Coal, bottom bench,	8′ 10″
Fire-clay floor,	4′ 0″
Total coal,	9′ 4″

At a point a short distance from opening No. 5 the same bed measured as follows:

Sandstone roof.	
Coal, top bench,	3′ 0″
Slate,	1′ 0′
Coal, middle bench,	1′ 3″
Slate and bony coal,	2′ 0″
Coal,	3′ 10″
Total coal,	8′ 1″

These three sections of the Jackson mine are sufficient to show that although the individual portions of the coal-bed are subject to local variations, as to thickness, yet the thickness of coal at any part of the mine is sufficiently great to make the bed a valuable one for practical operations.

No analysis was made, by the Survey, of the coal from this mine; the character of the coal, however, is such that no marked variations would be found between its composition and that taken from the larger mine to the east.

Accompanying the topographical map of the Loyalsock basin is published a map of the mines, drawn to a scale of 800 feet to 1 inch, and brought up to the last surveys made by Mr. P. E. Alden, in February, 1884. This map was examined by Mr. Clarence R. Claghorn, the present mining engineer of the State Line and Sullivan R. R. Co., in November, 1885. Although during the interval between these two dates probably as much as 125,000 tons of coal had been shipped from this mine, no great extension had been made of the mine workings beyond those shown on the accompanying map.

A number of sections have been measured of coal-bed B, in this mine. At a point 300 feet south from the mouth of Mine No. 3, the bed measured as follows:

Coarse sandstone roof.		
Coal, top bench,	3′	0″
Fire-clay,	2′	6″
Coal, middle bench,	1′	6″
Slate,	1′	1″
Coal,	0′	4″
Very hard sandy fire-clay,	0′	3″
Coal, bottom bench,	4′	0″
Fire-clay floor,	4′	0″
Total coal,	8′	10″

In some places in this mine the fire-clay underlying the bottom bench has been proved to be more than 10 feet thick.

In portions of the Jackson mine and the State Line and Sullivan R. R. Co.'s mine, the bottom and top benches of the coal-bed are so far separated that they are mined independently of one another. About 800 feet south-east of the point where the above section was measured, the top and middle benches are 7 feet apart, but about 200 feet further east from this latter point the top and middle benches are 11 feet apart. When the top and middle benches separate, the interval between the bottom and middle bench also thickens and the middle bench becomes so far removed from the bottom bench that it cannot be mined with it.

Mr. Clarence R. Claghorn, in November, 1885, reported that the bottom and top benches, at a point 1400 feet south of the mouth of opening No. 1, were 17 feet apart.

A bore-hole was drilled about 1000 feet south of east of opening No. 1, the record of which is reported as follows:

Surface, 1866′ above tide.		
1. Sandstone,	30′	0″
2. *Coal*,	3′	0″
3. Slate,	11′	0″
4. Fire-clay,	20′	0″
5. Slate,	4′	0″
6. Fire-clay,	10′	0″
7. *Coal*,	1′	3″
8. Slate,	2′	0″
9. Fire-clay,	9′	0″
10. *Coal*,	5′	0″
	95′	3″

Strata Nos. 2, 7, and 10 in this section are supposed to represent the top, middle, and bottom benches of coal-bed B. In drift No. 6 the following section of the bed was measured:

Coarse ferruginous sandstone roof,	15′+
Coal,	0′ 9″
Slate,	0′ 2″
Coal,	4′ 5″
Fire-clay floor.	
Total coal,	5′ 2″

The elevation of the mouth of opening No. 6 is 1877.5 feet above tide.

At a point indicated on the map, about 1100 feet southeast of Stroud and Ackley's saw-mill, a shaft was sunk to the bottom bench. The elevation of the top of the shaft is 1911.16 feet above tide. The elevation of the bottom of the coal is unknown, but it would probably be about 1881.5 feet above tide. It would therefore appear that the coal-bed dips from both this opening and the shaft opening near the saw-mill, toward No. 6 drift. The coal-bed also dips from the mouth of this drift towards its face; in consequence, no mining has been carried on at this point, since the drift goes below water-level. It is reported that the shaft to the bottom bench was 11 feet deep, the thickness of the coal-bed being about 5 feet, the coal being overlaid by sandstone.

A drift has been driven on a coal-bed on Pigeon run, located on the map at an elevation of 1902.5 feet above tide. This drift had fallen shut when it was visited, but it was reported that 8 feet of coal had been opened. It is probable that this opening was made in the bottom bench of the coal-bed.

Although considerable exploration work will have to be done before it can be stated with certainty the area in the Bernice basin underlaid by coal, or the average thickness of coal-beds which can be mined under this area, yet the facts which are at hand are sufficient to show that at the rate of mining carried on in the past there is sufficient coal in this basin to last for many years.

No estimates have been made by the Survey as to the area

which may be safely assumed to contain coal of a given thickness. In the report of the State Line and Sullivan R. R. Co., of December 1, 1885, it is estimated that on the property of this company alone there are 3000 acres underlaid by coal, and it is estimated that in this area there is contained 20,000,000 tons of coal.

The amount of coal contained under each acre will average about 10,000 tons, making a total of 30,000,000 tons. Of this total amount it is computed that 20,000,000 tons can be brought out of the mines, 4,000,000 out of that portion of the property at present opened, with necessary gangways, etc., and the remaining 16,000,000 tons in the area that is at present untouched. These figures are stated under the authority of the company and no comment can be made in regard to them, since the Survey has made no special investigation of the subject.

Composition.

The coal from the Bernice basin is probably more marked than any other coal mined in Pennsylvania, having the structure and physical appearance of a bituminous coal and the composition of an anthracite coal.

The high percentage of fixed carbon in this coal, the small amount of gas which is evolved upon heating, and the non-coking properties of the coal render it an unsatisfactory fuel to bituminous consumers.

Not until the Geological Survey had made numerous analyses of the Bernice coal, and had shown that it possessed a composition which would entitle it to be called an anthracite more than some of the softer anthracites mined from the western part of the anthracite region, and until the operators had designed a mechanical method of preparing the coal, and had succeeded in removing the prejudice of the coal trade and consumers against the coal which they had always been disposed to regard as bituminous and not anthracite, was the coal rated by the trade either as a competing fuel of the soft anthracites or as a specialty.

The free-burning character of this coal, the property it possesses of continuing to burn under conditions in which

fires made of other coals would go out, the easy, complete combustion of the carbon in the coal, and the open like tendency of the ash, which results from combustion, and which seldom has a tendency to clinker, renders the coal a desirable fuel.

Many of the analyses which have been made of this coal have already been published in Mr. Platt's Report GG, on the Bernice Coal-basin, and in Mr. McCreath's Second Report of Progress of the Laboratory of the Survey, Report MM. These are reproduced here for comparison, together with additional analyses made by Mr. McCreath in November, 1885.

"Specimens of the three benches of coal in bed B, as mined at Bernice, were forwarded to the Laboratory of the Survey for analysis. They yielded as follows (A. S. McCreath), taking the general average of all the benches together as they are shipped to market.

"The coal is bright, shining, compact, and shows considerable charcoal and iron pyrites."

Water,	1.295
Volatile matter,	8.100
Fixed carbon,	83.344
Sulphur,	1.031
Ash,	6.230
	100.000
Color of ash,	gray.
Carbon ratio,	1: 10.8

Of course it makes no coke, but is a *true anthracite*, and the above analysis represents fairly the character of the coal as furnished in quantities from the Bernice mines.

On analyzing separately the coal from the three benches the result was as follows:

"The coal is generally very firm and compact; it has a deep black shining luster and is seamed with bright crystalline coal. It carries considerable mineral charcoal in thin partings, and shows only a small amount of iron pyrites, existing generally in thin scales. The coal from the top bench has a seam of grayish-black cannel like coal running through it; but the other specimens seem almost

free from this. The coal does not coke and yields gases which burn with a very feebly luminous flame."

The top bench of coal yields:

Water,	1.840
Volatile matter,	9.835
Fixed carbon,	76.788
Sulphur,	.647
Ash,	10.890
	100.000
Color of ash,	cream.
Carbon ratio,	1: 7.8

This coal is nearly the same as the coal yielded by the middle and lower benches, but is not quite equal to them in quality, as it carries more ash.

The middle bench yields:

Water,	1.800
Volatile matter,	9.650
Fixed carbon,	82.373
Sulphur,	.622
Ash,	5.555
	100.000
Color of ash,	gray.
Carbon ratio,	1: 8.5

This is the purest coal of the mine.

The lower bench yields:

Water,	2.220
Volatile matter,	9.405
Fixed carbon,	81.267
Sulphur,	.618
Ash,	6.490
	100.000
Color of ash,	cream.
Carbon ratio,	1: 8.6

"This coal is up to or beyond the average character of the whole bed, and it is noteworthy that it carries a little more water than either of the upper benches.

Cannel slate layer. Mr. McCreath made an analysis of the grayish black cannel-like coal layer, running through the top bench of coal. It should more properly be called

the cannel slate layer, though the expression cannel slate scarcely applies to one containing so small a proportion of volatile matter.

The grayish-black cannel-like coal yields:

Water,	1.950
Volatile matter,	9.030
Fixed carbon,	63.795
Sulphur,	.583
Ash,	24.642
	100.000
Color of ash,	cream.
Carbon ratio,	1:7.0

Taking the *average of the analyses* of the coals from the three benches, it will compare with the analysis of the average run of the mine thus:

	Average of the benches.	*Average run of mine.*
Water,	1.953	1.295
Volatile matter,	9.630	8.100
Fixed carbon,	80.143	83.344
Sulphur,	.629	1.031
Ash,	7.645	6.230
	100.000	100.000
Carbon ratio,	1: 8.3	1: 10.2

It is curious how marked is the difference in the percentage of water and volatile matters. Variations and errors may be looked for in analyses of specimens from coal mines, however careful may have been the selection of the specimens. It should be mentioned here, however, that the *average* sample was selected in 1876, while the three samples from the different benches were taken in 1878, and the character of the coal may have changed as the mine was worked forward. The analyses taken together, however, establish clearly enough the general character of the coal; and it is a very remarkable one."

"Leaving out the accidental impurities, and counting only the ignitable constituents of the fuel, we have:

Fixed carbon,	91.142
Volatile matter,	8.858
	100.00
Proportion of volatile matter to fixed carbon,	1: 10.289

"But while the Bernice coal from bed B is thus clearly an anthracite, according to the trade classification, and a semi-anthracite, according to the classification suggested in this report, and is used for exactly the same purposes and in the same way as the other Pennsylvania anthracite coals, yet in its appearance and structure it differs much from them."

"It has a dull luster, instead of the well known shining luster of the other anthracites, and it entirely lacks the conchoidal fracture which is possessed by every other Pennsylvania anthracite."

"So different is it in physical structure that it cannot be passed through an ordinary anthracite breaker. (See Report GG, page 183.) Such a breaker would so crush it as to leave little beside slack and pea coal."

"About one and a half miles east of Bernice, at an elevation of 1945 feet above tide, Mr. Woodward, former superintendent of the mines, drifted on a coal-bed sufficiently far to make measurements of the thickness of the bed and to secure specimens for analysis. A section of the bed is as follows:

Coal, top bench,	1′ 3″
Slate and fire-clay,	6′ 0″
Coal, bottom bench,	3′ 8″
Total coal,	4′ 11″ "

Thirty feet of sandstone overlies this bed and the floor is composed of fire-clay. Specimens were collected from each coal bench and analyzed separately by Mr. McCreath.

"*Top bench.*"—The coal has a dull, dead luster; it is very soft and crumbling, and has a somewhat shaly appearance, with laminated structure. The gases burn with a feebly luminous flame, but the coal does not yield a coke.

Water,	7.980
Volatile matter,	21.410
Fixed carbon,	54.099
Sulphur,	.551
Ash,	16.010
	100.000
Color of ash,	cream.
Carbon ratio,	1: 2.5

"*Bottom bench.*"—The coal is deep black, hard and brittle:

Water,	2.910
Volatile matter,	11.780
Fixed carbon,	81.672
Sulphur,	.598
Ash,	3.040
	100.000
Color of ash,	cream.
Carbon ratio,	1: 6.9

The analyses of the coals of this basin already described have shown some curious features, but none so conflicting as the two analyses given above.

In the first place, the percentage of water in the coal from the top bench is unusually large, nearly three times as great as the percentage of water in the bench below, separated from it by only 6 feet of slate and fire-clay.

The carbon ratio.—Throwing out the accidental impurities, and counting only the ignitable constituents, we have for the top bench:

Fixed carbon,	71.646	1: 2.527
Volatile matter,	28.354	
	100.000	

But for the bottom bench:

Fixed carbon,	87.394	1: 6.932
Volatile matter,	12.606	
	100.000	

That is, according to the usual classification, the upper

bench is a bituminous coal, and the lower bench an anthracite.

From another opening in the top bench of this curious coal-bed, specimens were taken for analysis, on which Mr. McCreath reports thus:

"It was very wet when taken out of the box. The first analysis represents it in this condition. On exposure to the air of the laboratory for 16 hours it loses 8 per cent. of water, and this amount is not materially changed after 30 hours exposure. The second analysis represents the coal after it had been air-dried for 16 hours.

"The coal is, for the most part, in fine powder. It has a dull, dead luster, with a somewhat shaly appearance. It is very soft and crumbling, and has the same general character of the coal from the top bench, (previously analyzed,) see Report MM, page 94, analysis No. 938. The gases burn with a non-luminous flame, but the coal does not coke at all. As usual, it re-absorbs water very rapidly, just like the other Bernice coal.

"The analyses are as follows:

	Wet coal.	*Air-dried coal.*
Water, at 225° F.,	15.060	7.060
Volatile matter,	22.680	24.816
Fixed carbon,	50 993	55.796
Sulphur,	.372	.407
Ash,	10.895	11.921
	100.000	100.000

Color of ash,	reddish gray.
Carbon ratio,	1: 2.24"

From a personal examination of this opening and its surroundings it is believed that this coal-bed is a part of bed B, although the certain identification of the bed is not believed to have been made beyond question.

Analyses made in November, 1885, of the Bernice coal, are as follows:

	Specimens 1, 2, and 3.
Water at 212° F.,	.976
Volatile matter,	9.969
Fixed carbon,	81.236
Sulphur,	1.274
Ash,	6.545
	100.000
Color of ash,	reddish gray.
Carbon ratio,	1: 8.15

Specimen No. 2 contains more sulphur than either Nos. 1 or 3.

	Specimen No. 4.	*Specimen No. 5.*
Water at 212° F.,	.654	.650
Volatile matter,	9.501	9.405
Fixed carbon,	79.265	83.691
Sulphur,	.665	.909
Ash,	9.915	5.345
	100.000	100.000
Color of ash,	white.	gray.
Carbon ratio,	1: 8.34	1: 8.898

Specimen No. 1 was composed of 3 separate specimens of coal, which were collected from the top, middle, and bottom benches of bed B, in mine No. 3, about 600 feet from the mouth of the drift. At the point where the coals composing these specimens were collected, the top bench was 3 feet thick, the middle bench was 1′ 3″ thick, and the bottom bench was 3′ 6″ thick.

Specimen No. 4 was collected from the bottom bench of bed B, at the face of Brown's gangway, November 6, 1885. Specimen No. 5 was collected from the top bench of bed B, at the face of Hayes' gangway, November 6, 1885.

All these coals yield gases which burn with a feebly luminous flame, and they have not the slightest tendency to form a coherent coke. Mr. McCreath in remarking on these specimens at the time they were analyzed by him (it was not known to him where they came from,) says: "While they look very much like an ordinary bituminous coal, they are undoubtedly soft anthracite in their composition. They

burn freely without clinker, and for steam and domestic purposes they may be considered as a first-class fuel."

The peculiarities of the Sullivan County coals are so remarkable that they were the subject of a special investigation by Mr. McCreath. Mr. McCreath refers to these analyses* as follows:

"They are comparatively dry-looking coals, yet they all contain an unusually large percentage of water. After being thoroughly dried at 225° F., and then exposed to the ordinary atmosphere, they absorb water with great rapidity, so that in a few hours they have re-absorbed about sixty per cent. of the amount of water originally present, and this amount is not materially increased by longer exposure.

The following experiments were made with specimen No. 803, containing 4.13 per cent. water:

On drying, at 225° F., the coal loses, ...	4.13 per cent.
" " 245° F., " "	the same.
" " 260° F., " "	4.19 per cent.
" " 340° F., " "	4.50 per cent.
" " 460° F., " "	4.69 per cent.
At a dull red heat, ...	12.59 per cent.

"But in all these experiments the amount of water reabsorbed after exposure for a few hours to the ordinary atmosphere, remains practically constant; that is, the coal re-absorbs about 2.48 parts of water, and this property of absorbing water is not destroyed even after all the volatile matters have been driven off by heat. These 2.48 parts of water might, therefore, be termed *water of constitution*, and the remainder of the water — 1.65 parts — *hygroscopic moisture of pit water*. And it is to be noticed that this latter amount of water corresponds very closely with the average percentage found in the general run of the coals from this basin.

"In order to ascertain whether the total absorption was due to water, the following experiment was made: A portion of the coal was put into a flask, and, after being thoroughly dried, the whole was weighed; the flask was then tightly fitted with a chloride of calcium tube (to prevent

*Report GG, page 95.

the absorption of water) and allowed to stand in the ordinary atmosphere for twelve hours. It was again weighed, but no appreciable increase in weight was noticed. It was now allowed to stand for a few hours without the chloride of calcium tube attached, and when again weighed it was found that a considerable increase in weight had taken place, evidently due to the absorption of water. This property of absorbing water with such remarkable rapidity has been noticed in only a very few cases.

"These coals yield quite a large percentage of volatile matters, which burn with a *very feebly luminous flame*; but not one of them has the slightest tendency to form a coherent coke. And in this respect, also, they differ from most of the other coals examined. It seems safe, therefore, to assume that they result from a peculiar kind of vegetation, deficient in illuminating hydro-carbons, and different in many respects from that forming the great bulk of the bituminous coals of this State.

"Another very interesting point may here be noted. In the coal opening, one and a half miles east of Bernice, (analysis Nos. 938 and 939,) we find in the same mine, separated from each other by only six inches of slate, a bituminous coal (upper bench) with a fuel ratio of 1 : 2.52, and a semi-anthracite (lower bench) with a carbon ratio of 1: 6.93. Or, taking the sum of the volatile combustible matters and fixed carbon as 100, we have the ignitible constituents in the following proportions:

	Upper bench.	*Bottom bench.*
Volatile combustible matters,	28.36	12.61
Fixed carbon,	71.64	87.39
	100.00	100.00

The existence of a bituminous coal-bed in the Bernice field, or a bituminous bench of a coal-bed composed of several benches where all but one may be anthracite, can have no practical bearing upon the composition or classification of the coal which the State Line and Sullivan R. R. Co. are at present mining, since all the analyses which have been made of the coal which has been shipped to market from the Bernice basin prove that it is an anthracite coal.

Notes on the Mehoopany Coal-field.

While Mr. E. B. Harden was surveying the Sullivan county part of this area, Mr. Frank A. Hill made a reconnoisance of its eastern end with a view to the extension of the Survey eastward into Wyoming county. This reconnoisance was commenced at Mehoopany, August 27, 1883.

The contact of Catskill (IX) with Chemung (VIII) is at the mouth of the Mehoopany creek. The elevation of the Lehigh Valley R. R. station at Mehoopany is 634.5 feet above tide.

Forkston is five miles up the creek, at the forks of the north and south branches, and about 120 feet higher, approximately 750 feet above tide.

Massive conglomerate rocks horizontally cap the mountains. In this neighborhood no ravines descend the north face of the mountain into the valley of the North branch, all the streams of the mountain plateau flow south and east, cutting down into the South branch. This of itself shows a gentle dip of the rocks of the mountain towards the south, the North branch cutting eastward against the basset edge of the stratification.

That there is a gentle south-west fall of the mountain rocks is shown by the fact that the coal crops on the Forkston mountain are higher than those of Bernice, in Sullivan county.

Up the South branch, about a mile above Forkston, is Squire Spaulding's house.

The easternmost coal opening (No. 1) is about half a mile from Squire Spaulding's house, on the crest of the mountain west of the South branch.

Another coal opening (No. 2) (F. Chrisman) is on the mountain crest between Stony brook and Spring brook. Here a gangway has been driven 390 feet, and a number of breasts have been turned. The operators report 1000 tons mined.

The bed is quite regular, thus:

At mouth:

Top, massive conglomerate.		
Coal,	2′	10″
Bone,	0′	7″
Fire-clay,	4′	4″

260 feet in the gangway:

Top, massive conglomerate.		
Fire-clay,	0′	5″
Coal,	3′	2″
Bone,	0	6″
Bottom, fire-clay.		

Section of the bed at face, 390 feet from the mouth:

Top, massive conglomerate.		
Coal,	2′	6″
Bone,	0′	4″
Bottom, fire-clay.		

This (No. 2) Chrisman opening is about 2100 feet above tide, or more than 200 feet higher than the lowest coal-bed at Bernice, a good argument for the Chrisman coal-bed being above the Mauch Chunk Red Shale, No. XI, and very probably in the body of the Pottsville Conglomerate, No. XII.

The rise of the measures eastward justifies Professor White in assigning the whole of Wyoming county east of the Susquehanna river to the Catskill formation, No. IX.

Daddow's opening, (No. 3,) mentioned by Mr. Platt in Report of Progress GG, page 205, is at the west end of this same coal area, (between Stony and Spring brooks,) where the descent is westward to the head springs of the Loyalsock, near the county line. This is, in fact, the highest land of this part of the region.

Daddow's opening is more than a mile west of Chrisman's opening, and the outcrop is continuous between them, there being another opening (No. 4) on the coal half way between them.

Going up the Mehoopany south branch from Forkston, five large brooks descend from the flat crest of the very high mountain divide between it and Bowman's creek. These are in order, (going south-west,) Scouten brook, Cassen brook, Henry Lott brook, Somers brook, and South brook.

Scouten brook enters the south branch two miles south of Forkston. It descends from the mountain south-east of Forkston.

Coal smut is reported on the Polly Elliott and William Hall tracts at the headwaters of the Scouten and Cassan brooks, but nothing definite is known about it.

At the head of the Henry Lott brook a very high summit commences and extends south-westward, past the head of Somers brook, to the head of South brook. Coal is said to appear at the head of these three brooks.

The divide continues on south-west across the Wyoming county south line into Luzerne county, and a sixth large brook descends into the Mehoopany south branch a mile or more higher up than South brook. At the head of this, also, coal appearances are reported.

All these mountain-top areas are faced by massive conglomerate, which seems to be the same, and, therefore, ought to cover the same coal-bed, whether in workable condition or not can only be told by experiment.

There is no perceptible dip, although very careful spirit-leveling would, of course, show that the horizontality is not perfect.

The same state of things exists westward across the Sullivan county line and around Lake Ganoga. The rocks there described in Report GG as Pocono sandstone, No. X, resemble in a marked manner the rocks capping the mountain west of Forkston, which seem to be Pottsville Conglomerate, No. XII.

There are two conglomerates in these areas, both specially well defined on Stony brook; one above the coal-bed, coarse and heavy; the other under the coal-bed, less coarse and interleaved with sandstone beds.

The upper or roof conglomerate has a thickness of 40 feet where best exposed. The lower conglomerate and sandstone mass seems to be from 250 to 300 feet thick.

In the midst of this lower mass is seen a little coal a few inches thick.

From the bottom of this lower mass issue chalybeate springs depositing bog iron ore. This was a mark by

which, in the First Geological Survey of the State, the top of the Mauch Chunk Red Shale formation, No. XI. and the bottom of the Pottsville Conglomerate formation, No. XII, were always recognized, especially in south-western Pennsylvania along Chestnut Ridge and Laurel Hill. See the reports of 1837 to 1841.

This is the place of the iron ore bed of Somerset county, the Queen's Run ore of Clinton county, and the Ralston ore of Lycoming county, etc.

A solid bed of ore is exposed on Pigeon run, near Ganoga lake, in Sullivan county, in this situation, and again on Ore run, where Col. Rickets obtained the following section:

Soft yellow and whitish shales,	10′	0″
Ore, bluish and greenish gray,	0′	4″
Slate, greenish,	0′	3″
Ore, same as above,	1′	3″
Slate, greenish,	1′	0′
Ore, same as above,	1	7″
Shale, reddish,	5′	0″
Ore, same as above,	1′	0
Shale, reddish,	1′	0

A section (barometric) taken on the mountain slope descending Stony and Red brooks to the Mehoopany south branch, shows the following:

Conglomerate (roof of Chrisman's coal,) visible,	25′	0
Coal bed,	3′	5′
Interval concealed,	100′	0
Interval to where red wash in stream stops,	50	0
Sandstone slaty and sandstone yellow,	90′	0
Conglomerate, massive,	40	0″
Red shale with some yellow shale,	120	0
Sandstone, gray and yellow,	30′	0′
Interval concealed,	10′	0″
Red shale,	3′	0″
Interval concealed,	30′	0″
Sandstone, greenish gray,	35′	0″
Interval concealed,	85′	0″
Occasional slight exposures of sandstone,	420	0
Shale, white,	3	0″
Red shale,	35′	0″
Sandstone, greenish gray,	45′	0″
Shale, white,	0′	8″
Red shale,	—	—

We have here the following series:

Conglomerate, coarse, heavy, about		40′
Coal bed,		3′
Shale, red, etc.,		150′
Sandstone,	90	130′
Conglomerate,	40	
Red shale,		120′
Sandstone and soft intervals,		615
Red shale,		35′
Sandstone,		45′
Red shale,		—

In other words, the top of the red shale mass seems to come from beneath the coal and just under the lower conglomerate. The question is, Is this No. XI or is it No. IX?

If it be No. IX, the Pocono formation No. X is represented by only 130 feet of sandstone and conglomerate, and the Mauch Chunk Red Shale No. XI by 150 feet of soft interval just under the coal, which will then be the Campbell's Ledge plant bed as Mr. White supposes.

But if it be No. XI, then the coal-bed is near the top of the conglomerate, which will then be about 300 feet thick, as it is all through Western Pennsylvania.

Professor Lesley's surveys on the Towanda mountain, in Bradford county, (not more than 20 miles distant to the north-west,) made with instruments of precision, gave the following section:

Conglomerate and sandstone,	60′
Coal-bed,	1′
Sandstone,	80′
Iron ore bed, solid,	3′
Sandstone,	70′
Red shale of No. XI in force,	—

The creeks in the Mehoopany areas generally head in the supposed Pottsville Conglomerate, No. XII, cutting their way down through horizontal measures into Catskill, No. IX. A series of carefully measured detailed sections, for comparison, and a good topographical map of the North mountain region, would throw a great deal of much needed light on the geology of this region.

MODEL OF THE CORNWALL IRON ORE MINES. LOOKING NORTH.

HELIOTYPE PRINTING CO BOSTON, MASS

Report on the Cornwall Iron Ore Mines, Lebanon County.

By J. P. LESLEY and E. V. D'INVILLIERS.

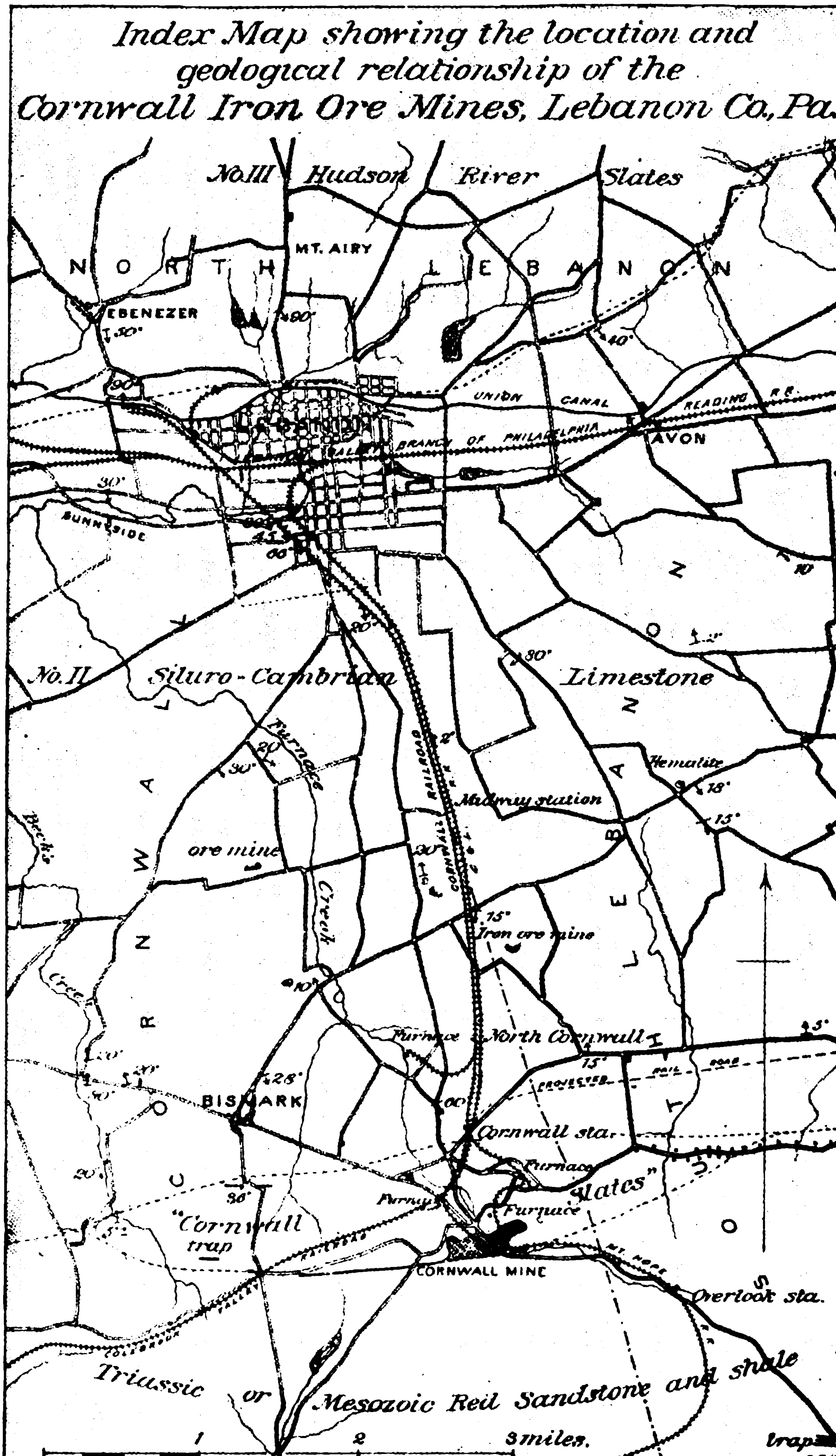
These magnetic iron ore mines are situated on the southern border of Lebanon county, half way between the Schuylkill and Susquehanna rivers, in three hills standing in front of the Mesozoic red shale and sandstone hill country of northern Lancaster, overlooking the great limestone plain of the Lebanon valley, here about 5 miles wide.

The three hills, separated from each other by two branches of Furnace creek, and ranging in a west south-west direction for a distance of about one mile, are known as *Big hill* at the east, *Middle hill*, and *Grassy hill* at the west; the elevation of their summits being, in round numbers, respectively 900, 700, and 700 feet above tide; and that of the railroad line across the plain, 575.6 opposite Middle hill at Cornwall, and 471 at Lebanon.*

In the last century these hills had smoothly rounded summits, composed of weathered ore, of great purity to the depth of several feet or yards, beneath which lay the mass of ore constituting the whole body of each hill, now extensively removed by open quarry work down to water level. But the quantity of ore still remaining above water level is greater than the quantity removed; and at several points the original hill-top surface-ore has been left untouched; while beneath water level the ore mass is known (by borings) to descend to a depth exceeding 300 feet.

The extreme length of the uncovered ore mass is about

* Photograph plate, opposite page 491, is a view of a model of the Cornwall mine, made by Mr. E. B. Harden, by cutting veneering stuff to the contour lines of Mr. d'Invilliers' map of the mine, and filling the steps with wax. By this method the upper edge of each veneer represents its corresponding contour line. The point of view is high in the air and from the south. The view of Mr. Lehman's model, described in foot-note to page 495, exhibits the hills as they would be seen from the north, against a back ground of Mesozoic hill country.


Index Map showing the location and
geological relationship of the
Cornwall Iron Ore Mines, Lebanon Co, Pa.
No.III Hudson River Slates
MT. AIRY
NORTH LEBANON
EBENEZER
UNION CANAL
READING R.R.
AVON
SUNNYSIDE
No.II Siluro-Cambrian Limestone
SOUTH LEBANON
CORNWALL
Furnace
ore mine
Creek
Hematite
Midway station
CORNWALL RAILROAD
Iron ore mine
North Cornwall
Furnace
BISMARK
PROJECTED RAIL ROAD
Cornwall sta.
Furnace
Slates"
Furnace
"Cornwall trap
CORNWALL MINE
Overlook sta.
Triassic or Mesozoic Red Sandstone and shale
1 2 3 miles.
trap

4400 feet; its breadth in Big hill 400, in Middle hill 800, in Grassy hill 600; and its estimated total area is nearly 63 acres.

The north brow of Middle hill, the north and west brow of Grassy hill, and the north, east, and south brow of Big hill, is an outcrop of dolerite trap, the fallen fragments of which cover the outside steep slopes. The steeply sloping trap dyke is exposed on the opposite sides of each of the two gaps, descending from the hill tops to water level, with an apparent width of about 100 feet. Beneath water level the trap dyke is, of course, continuous from the east end of Big hill to the west end of Grassy hill. where, bending towards the south-west and south, it disappears beneath the Mesozoic highland. The ore-mass lies banked against the sloping south face of the trap, therefore overlying it and abutting against it. The rocks that underlie the trap and outcrop on the northern slope are covered with a sheet of fallen trap fragments and are therefore very little known.

The edge of the ore-mass, as shown by the map, is far from being a straight line, but follows the irregular course of the trap, which changes several times in an unexpected manner, showing that the lava forced its way up through an irregular crack, and therefore that the dyke must be of different widths at different places. Along the north side of Big hill the line of trap is straight S. 77° W. for 800 feet; then straight S. 62° W. down the nose of Big hill, across Furnace creek valley and up the nose of Middle hill, 1400 feet; then at a sharp angle N. 74° W. slightly curving to the summit of Middle hill, 500 feet; then S. 60° W., continuing the same curve down the west slope. 500 feet; then at a sharp angle N. 81° W. straight across the little valley to the foot of Grassy hill, 800 feet; then N. 55° W. up to the summit of Grassy hill, 400 feet; then S. 65° W. along the summit, 300 feet; then S. 10° E. to the forks of the Mt. Hope road, 500 feet; then turning S. W. its course is not known; 5200 feet in all. following the devious course of the dyke.

The course of the trap on the south side of Big hill is S. 67° W. for 600 feet.

Big hill is cut off from the Mesozoic highlands to the south by the valley of Furnace creek, which heads 1½ miles east south-east of the mine, and descends from a notch in the Dividing ridge (or South mountain, as it is improperly called) through which the Cornwall and Mt. Hope railroad passes, the summit level of the railroad in the notch being 845′ A. T. The gradient of this railroad down the valley to Cornwall is about 175′ to the mile, and its grade level at the mine, in front of the superintendent's office, 585′ A. T. Furnace creek, at the Weigh house on the Cornwall railroad, is about 570′ A. T.

Big hill summit (north side of the mine) is 870′ A. T.; the highest point of trap on its north side, 860′ A. T.; the highest point of trap on its south side, 850′ A. T. This is almost the level of the railroad summit grade in the notch of the Dividing ridge at the head of Furnace creek.

The Dividing ridge rises to about 1100′ A. T. east of the notch. West of the notch it rises for ½ mile to 1040′ A. T., and the crest runs on S. 77° W. at about this elevation for ¾ mile and then descends into another slighter notch, (960′ A. T.,) after which it rises again to 1075′ A. T., and so continues westward as high land between the parallel valleys of Little Chicques creek on the north and Chicques creek on the south; the latter heading up at the railroad notch and affording an avenue for the railroad down grade towards Mt. Hope.

The Dividing ridge runs at a distance of about a mile (5700′) south of the ore mine. Its northern slope is broken by a series of descending gullies, one of which is a deep ravine by which Sadtler's run descends into Furnace creek at a point 1400 feet south of the ore mine. A side branch of Sadtler's run comes in from the west, and between the two stands an isolated knob 975′ A. T. This knob is 3200′ due south of the ore mine (at the S. W. corner of Middle hill,) and on this knob Mr. Grubb has recently drilled a bore-hole 1000′± deep in an attempt to prove the southern extension of the ore. The futility of any such trial-hole on the flank of the Dividing ridge will be explained in a future section of this report.

MODEL OF THE CORNWALL IRON ORE MINES AND VICINITY. LOOKING SOUTH

HELIOTYPE PRINTING CO BOSTON, MASS

North of the west branch of Sadtler's run, and between it and the ore mine, runs another ridge, the highest point of which is 2400′ south of the west end of the ore mine, and its elevation 1025′ A. T. This ridge runs from west to east, and ends where Sadtler's run enters Furnace creek. East of Furnace creek there is no distinct ridge to represent it for a mile; but then it reappears and continues eastward north of the Dividing ridge.

North of it, and 800 feet east south-east of the east end of Big hill, is Sheep hill, separated from Big hill by a notch, through which the spiral railroad ascends, railroad grade in this little notch being 775′ A. T.

Sheep hill has a trend N. 62° E., nearly parallel with that of the ore mine and with that of the Dividing ridge, and merges eastward into a much higher hill, Templeman's, the knob of which is sharp and 985′ A. T.

Templeman's knob bears N. 58° E. from the west end crest of Sheep hill, distant 2800 feet. It bears the same (N. 58° E.) from the knob before described as overlooking the west end of the ore mine, distant from Templeman's knob nearly 2 miles (9200′.)

I consider this strike line of N. 58° E. thus obtained a very important factor in any discussion of the geology of Cornwall. It helps to rectify the observations of dip in the various obscure exposures of the Mesozoic strata, giving to them a general normal dip towards N. 32° W.

The strike of the Dividing ridge west of the railroad notch is, as has been said, N. 77° E., and this is about the run of the contour lines along its northern flank, and also the course of the straight water line of Chicques creek. But if a line of several miles be taken along the Dividing ridge the normal strike is seen to be N. 67° E.

Most of the features thus described will be more clearly understood by reference to the contour line map accompanying this report, and the relief view of the model of the same territory, constructed by Mr. A. E. Lehman from data contained on that map.* (See photograph plate, opposite page 495.)

* The model has the same scale as the map, 400′=1″, and was built up in card-board layers without vertical exaggeration, each layer of paper represent-

In spite of local variations (like that of the exposure on the railroad about a quarter of a mile east of the Miners village, ascending to the notch, where the dip seems to be N. 10° E.) it may be said that the whole Dividing ridge country of Mesozoic red shale and sandstone consists of parallel ridges of harder outcrops separated by side ravines of softer rocks, all dipping north-westward, or north-north-westward towards the ore mine and limestone valley of Lebanon county, at angles varying between 10° and 20°.

Now, as this formation belongs to a much later age than the Palæozoic formations of the Lebanon valley country, under which the N. N. W. dip would carry them if it were continued, we are obliged to believe that the Mesozoic dip stops somewhere; that it stops along a line, the south edge of the Lebanon valley limestone country; and that this line is the line of a great fault, on the north side of which the older limestones are *thrown up*, and on the south side of which the newer red shales are *thrown down.**

It will be shown in this report that this line of fault must run along the south edge of the Cornwall ore deposit; that the outburst of trap is a consequence of the fault; and that the Cornwall ore-mass owes its origin to and has had its size and shape determined for it by the fault and the trap combined.

In describing it, it will be convenient to describe, first, the range of trap; then the ore mass itself, with its included limestone beds; then the exhibitions made by the edge of the Mesozoic shales; then the surrounding areas of slate and limestone of the Lebanon valley, so far as their structural relationships can be made out; after which will

ing a vertical height of 10'; the lowest contour being 530' A. T.; the highest, 1075' A. T. The bottom edge of each sheet conforms to the corresponding contour, the edge of the sheet being bevelled back to the contour line next above. This method, when neatly executed, is as accurate as the other, and is better for cross section and railroad location work, because it preserves the contour lining of the map on the surface of the model. The area represented by this model is about 6 square miles; and the assumed point of view about 5 miles to the north of the mine and 2½ miles in the air.

* For this opinion, and everything in this report involving the theory of a downthrow fault between the New Red country and the Valley limestone and Cornwall ore mass, I only am responsible.—J. P. LESLEY.

be given a description of the mining operations, statistics of yield, etc.; and finally a history of the property, compiled from the records of the courts.

The Cornwall trap rock.

It has been said that the northern brow and present summit ridge of Grassy and Middle hills, and the north and south brows and east end of Big hill, represent an originally unbroken and continuous outcrop of igneous rock, (lava, trap, or dolerite,) now worn through down to water level by the two branches of Furnace creek. In the gaps the great thickness (say 100 feet) and the general southward pitch (30° to 40°) of the dyke are plainly visible, although no exact measurements can be made, because the bottom or northern wall of the dyke is concealed by the sheet of fragments which cover the slopes, not only in the gaps, but on the outside of the hills; but in the cuts of the spiral railroad ascending Big hill 60 or 80 feet of trap is passed through. With the fragments of trap are mingled pieces of black magnetic iron ore, which have slid down from the original summits of the ore hills.

The bearings and distances of the trap dyke have already been given.

The trap rock is a fine grained gray dolerite, varying in color with its percentage of feldspar; generally finely crystalline, varying but little in the size of its grains.

Dr. F. A. Genth's analyses of two varieties, given in Report B, p. 222, show the following constitution:

Dolerite trap.	*Coarse grained.*	*Fine grained.*
Specific gravity,	3.009	2.999
Silicic acid,	53.09	53.88
Alumina,	14.97	14.33
Lime,	11.24	10.92
Magnesia,	6.50	7.25
Ferric oxide,	6.13	3.23
Ferrous oxide,	4.47	6.54
Soda,	2.10	2.08
Potash,	0.69	0.96
Titanic acid,	0.90	1.09
Phosphoric acid,	0.16	0.10

Chromic acid, ...	trace	0.06
Manganous oxide, ...	trace	0.09
Ignition, ...	0.40	0.23
	100.65	100.76

The north wall of trap in Big hill seems to be inclined about 40° to the south-east, the east wall dipping to the south-west, and the south wall standing in the different cuts at angles varying from 78° and 80° S. 30° E., to 80° and 60° north-west.

The dyke nowhere presents regular upright faces, cutting off the ore sharply ; on the contrary, its face presents hummocks or shoulders between which the ore is found and mined, giving an exceedingly irregular contour facing the ore.

Where the ore has been stripped from it a columnar prismatic structure can be noticed, the columns being from six inches to a foot long. In some places the prisms, two to four inches thick, radiate from a central point. This fan-shaped structure is especially noticeable in the south wall, where the prisms vary from three to eight inches thick. (See photograph plate, opposite page 501.)

Along the flat of Furnace creek, between Big and Middle hills, we have facts going to locate the *north* wall of trap underground. Bore-holes have been put down there through the ore body to the upper surface of the trap, fixing with comparative certainty the inclination of the north wall *southward*, at an angle of about 38°. The position and depth of these bore-holes are shown on the map.

Midway between the two opposing walls of trap of Big hill, and on a terrace 35 feet higher than the Furnace creek flat, bore-hole No. 5 struck trap at 50′ feet. This hole was located, as nearly as possible, between the two trap faces, and is generally regarded as proof of the regular basin-shaped character of the dolerite.

This I am inclined to doubt, and think it still more probable that it was an offshoot of the *north* wall struck. This matter will be discussed further on. To be sure, at the western extremity of Big hill the south wall of trap ap-

pears to have a north-west inclination. But it certainly stands at much higher angles than the north wall, and, if the walls converge at all, their meeting would be in a vertical plane south of the central line in Big hill. But this is conjectural.

The whole south trap wall of Big hill shows the greatest irregularity in its outcrop, immense dome-shaped shoulders protruding into the body of the ore mass, around and behind which mining has been carried on as in the main deposit.

A small cross dyke shoots out from the main south wall in a N. 25° E. direction, passing right through the ore deposit to the north wall, and thinning in that direction from 3 feet to about 3 inches. It shows quite a distinct but imperfect columnar structure and slopes S. 65 E°. 50°.

Another similar cross dyke cuts across Middle hill in a N. W. course, dipping about N. 60° E., and thins out in the same way northward. In neither case does the trap seem to have risen high through the ore mass.

In the Big hill, especially on the north side of the upper and second levels, the ore mass is rendered rather unattractive by knobs of trap sticking up from the surface; but they have been met with elsewhere, and they offer no great obstacle to the successful prosecution of mining.

In the *Middle hill* there is no bounding wall of trap on the south, but whether it is still to be met with in mining towards the red shale country, or is entirely absent on that side is not yet known.

It would seem, however, that the latter view is more tenable; for, besides a westward prolongation of the bounding wall of Grassy hill, and a direct turn *southward* in the south wall of the Big hill dyke where it meets the Cornwall pike at the carpenter shop, there is no evidence of a south trap wall to Middle hill along the valley of Furnace creek.

A glance at the map, however, will show a curious and interesting shape which the *north* wall has assumed in Middle hill. It may best be compared to a crescent with its ends reversed or turned back (northwards.)

TRAP ON THE SOUTH SIDE OF THE CORNWALL BIG HILL, WHERE THE SPIRAL RAILROAD ENTERS THE UPPER WORKINGS.

The summit line of the dyke rises from the valley of Furnace creek at an elevation of 570′ A. T. to an elevation of 715′ A. T., at a point just opposite the center of the hill; from there it declines again westward to the creek which separates Middle and Grassy hills, at about 600′ A. T.

Near the center of the crescent the dyke, elsewhere deeply corrugated, becomes additionally marked with four protruding tongues striking south-westward into the ore deposit. This feature is illustrated in plate, page 502.

Proceeding in order eastward, each successive tongue projects a little farther south-westward than its predecessor. All are practically parallel, presenting clean and smooth faces on their inner sides, dipping south-east about 40°, but with broken, rough faces on their north or outward sides, exposing planes dipping north-west about 80°.

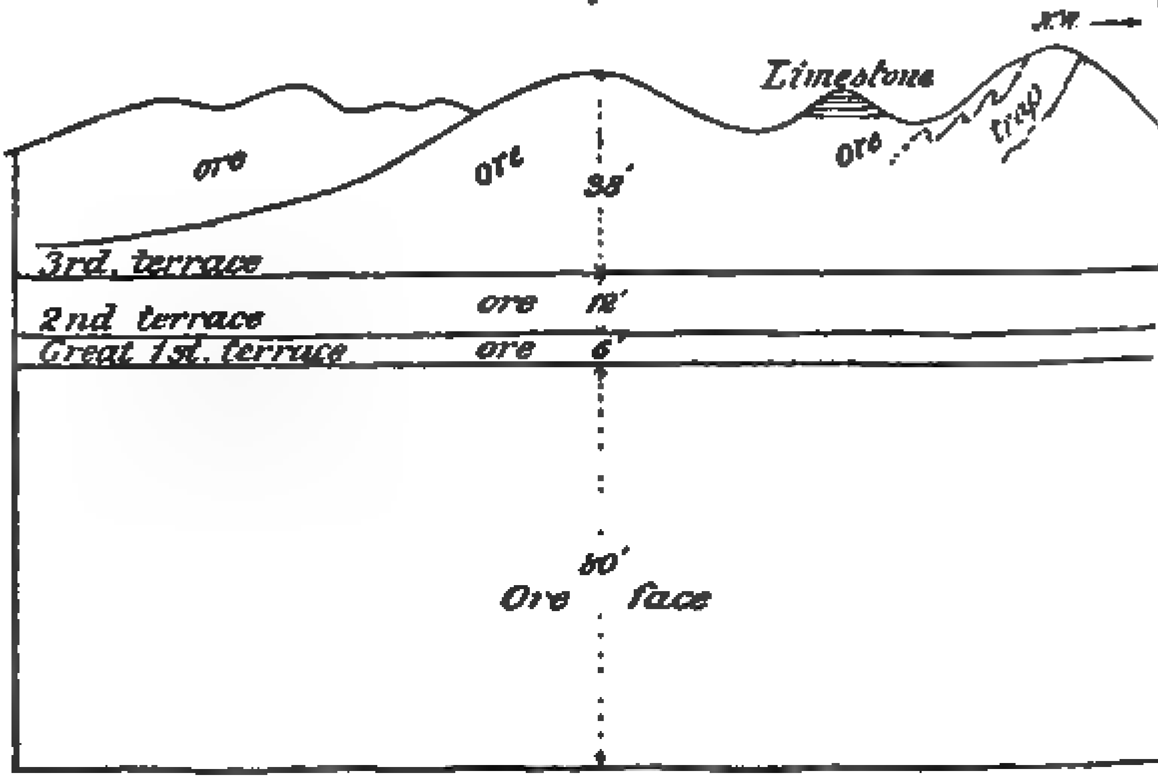
Back of and within each groove ore has been mined, but there is little evidence to show that the ore-body extended over the tops of these rolls so as to make one compact mass, at least within mining periods.

From the east end of Middle hill the dyke trends a little north of west in a practically straight line to the railroad cut in Grassy hill. It encircles the north and west sides of this hill in a horse-shoe shaped dyke, striking nearly due south at the west end until within close proximity to the branch of Furnace creek, and then bearing west south-west across the Mt. Hope road along the junction line of the slates and the New Red formation.

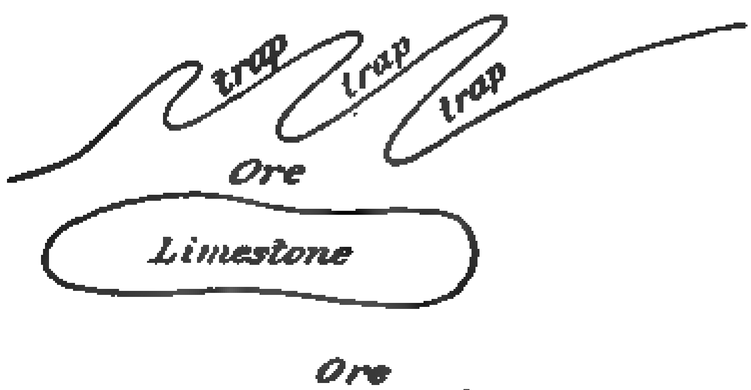
The Grassy hill dyke is in every way identical in character and composition with its eastern prolongation in Middle and Big hills, showing the same shoulders and irregularities of contour, and the same tendency to rough and imperfect crystallization.

The irregularities of the steeply sloping upper wall surface of the trap against which the gently south-west dipping strata of the ore mass abut abruptly (as shown in photograph plate opposite page 509,) are no doubt original to it as an outflow of lava from below, and were not produced at any after time by other circumstances. The shape of the trap surface as uncovered by mining operations was the

Diagram sketch of stopes in Middle Hill.



Relative positions of prongs of trap and limestone peak.



Sketch view of prongs of trap from the S.W.

shape of the wall of the fissure made by the trap in forcing its way upwards through the ore slates. The resistance was enormously great, and the tongues of trap described above (see also photograph plate opposite page 505) prove that the ascent of the lava was stopped in some places sooner than in others; that it never reached a higher level in those special parts of the dyke; and this renders it probable that even the thickest parts of the trap now forming the hill crests did not originally rise many hundreds of feet higher into the overlying formations, which have since been washed away, carrying the thin upper part of the trap with them. But that it rose higher than the present hill tops is evident from the fact that the crests have the aspect of outcrops of erosion, like mountain crests in the State.

If this view be correct, we may safely think that the trap increases in thickness downwards, and unites with some vast mass of trap at a great depth in the earth's crust; and this would connect the trap of Cornwall with all the other trap dykes of Lancaster county, and perhaps with all the traps of south-east Pennsylvania.

The most remarkable point is that this great upburst of lava shows no signs of having bent, folded, displaced, or affected in any violent way the ore strata. They repose quietly against its surface as if against a previously established cold and solid wall. (See photo. plate opp. page 509.)

The two gaps, which separate into Big, Middle, and Grassy hills the north range of trap, are ordinary water gaps and require no explanation; but the termination of the trap at the end of the hook in the south wall of the Big hill, although somewhat shortened by water erosion, is evidently like the four tongues already described, a plain proof that the lava could open and force its way into and through the mass of strata only a certain distance and no further. It must be noted that the hook of trap occurs at the east end of the mine, but no corresponding hook exists at the west end. In other words, a hook was formed at the end towards which the ore slate stratification rises, and not at the end towards which it dips. This agrees exactly with the hooking of one end of all the trap dikes of the Connecticut

river valley. The mechanical explanation of this phenomenon has been known for many years,* viz: that the trap ascended vertically until it could lift the strata and tear them apart in a curve. Here at Cornwall the operation went to the extreme of making not merely a curved rent, but a complete sharp hook.

An important conclusion may be drawn from this fact, namely, that the west end of the trap range must pass on underneath the Mesozoic strata and carry the down-sloping ore mass with it, still resting against its steep upper wall surface.

The hard wall of trap, by the resistance it has offered to the general weathering down of the whole region, has preserved a part of the ore-mass which would otherwise long ere this have been slowly swept away. Part of the trap has gone; how much we know not. Part of the ore-mass has gone; probably a far greater portion than has been preserved.

The Cornwall ore-mass is evidently a regularly stratified formation sloping down south-westward against the edge of the Mesozoic rocks, and rising north-eastward into the air where it is worn off at the top of the Big hill, but beyond which it must have originally extended at a continually higher and higher level, as far as the trap extended, how far we have no means of knowing. And this regularly stratified formation has been, in some way, converted into ore, retaining its place and form in all essential particulars. Whatever the process was, its effects at Cornwall are precisely like its effects at the Fritztown, Jones, Reading and Boyertown magnetic ore mines, and at the great brown hematite mines in Centre county and elsewhere.†

The Cornwall ore-mass.

Having described the wall of trap enclosing the ore-mass, the structure and composition of the ore-mass itself will now be described, with the limestone and undecomposed lime-shale layers which evidently make part of it, and a

* Worked out by James D. Whelpley, the geologist, about the year 1833.

† See Reports D[3], vol. 2, and T[4].

HELIOTYPE PRINTING CO., BOSTON, MASS.

TONGUES OF TRAP ON THE CORNWALL MIDDLE HILL. (LOOKING EAST)

LIMESTONE IN THE RIGHT HAND CORNER OF THE FOREGROUND

remarkable exhibition of finely conglomeritic sandstone which was met with at only one place completely enclosed in the body of the ore. Until all these features are clearly comprehended it would be useless to attempt to draw any conclusion or even express a conjecture respecting the origin of this wonderful deposit.

The thickness of the ore-mass.

What first strikes the observer is the unusual depth of the ore deposit, in full view, as measured by the eye, from the hill tops which still remain to the great water plain at the level of the streams. These stopes and terraces of the Big hill in one direction, and of the Middle hill in the other, are very impressive.

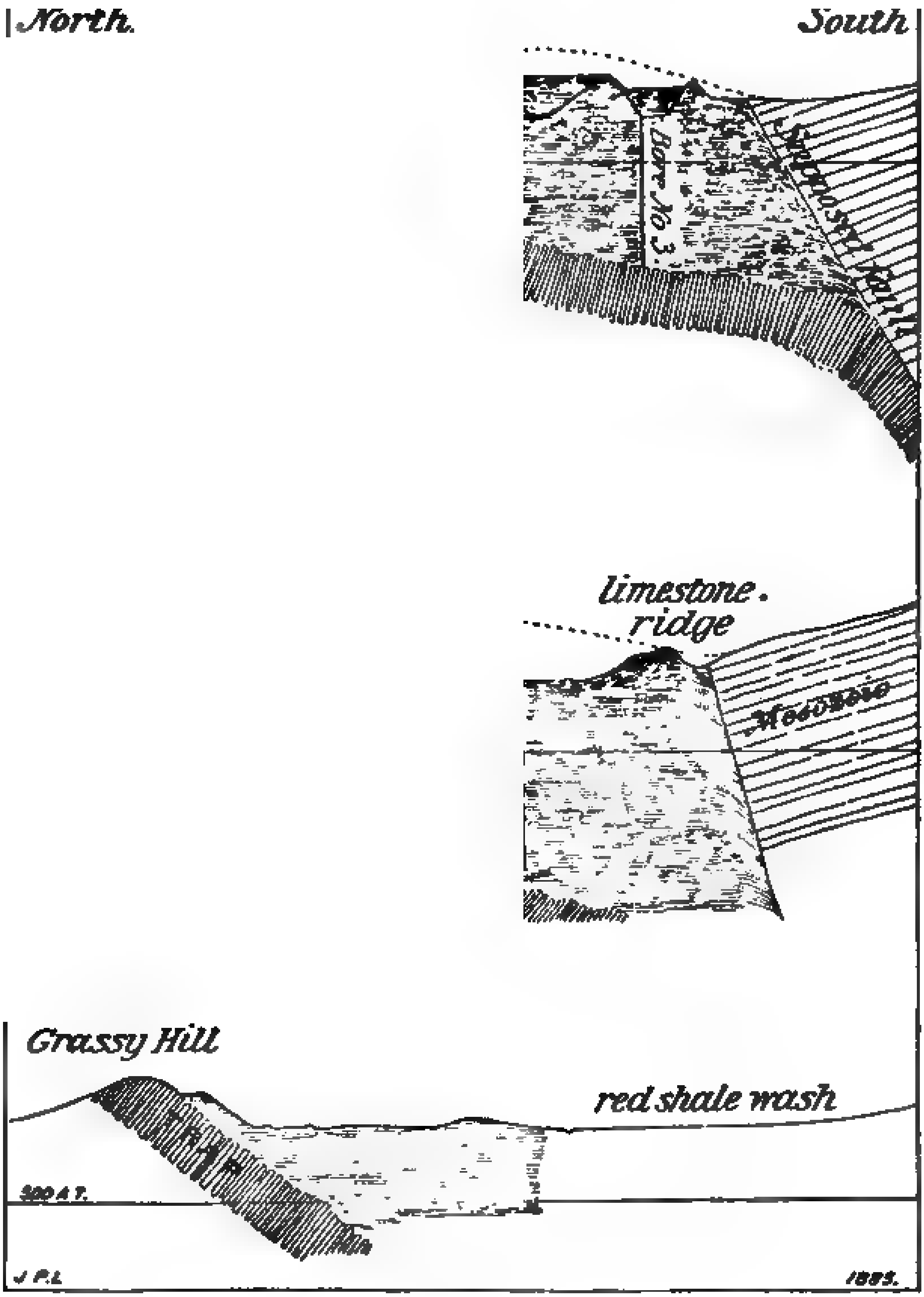
The water plane of the mine is about 570 feet above tide, and the first or high stopes rise from this.

In the *Big hill* the first stope is 40 feet high. From the terrace above, the second stope rises 120 feet. From the second terrace the third stope rises 50-60 feet. The highest point of ore, the present summit of the Big hill, is 300 feet above the water plane.

In the *Middle hill* the first stope rises from the water plane 80 feet, with a length of 500 feet, measured along its top edge from the trap wall southward to the entrance of the great through cut which is being driven through the middle of the hill. The first terrace is 200 feet wide to the base of the *second stope*, which is 6 feet high. The second terrace is 30 feet wide to the face of the *third stope*, which is 40 feet high. The third terrace replaces the original hill top. (See page 502.)

The Middle hill has been worked back from the creek westward 450 feet to the foot of the first stope. At its southern side a wide cut has been begun through the hill, on the water plane level, and in November last had reached a length of 150 feet, making 600 feet in all from the creek, the height of the ore at the head of the cut being then 60 feet.

The depth of the ore mass *beneath* the water plane near the creek was tested by three bore-holes, marked No. 1,


North.
South
Bore No 3
limestone.
ridge
Grassy Hill
red shale wash
J.P.L.
1885.

No. 2, and No. 3, on the map. No. 1 is the furthest north and within 140 feet of the trap, which is struck at a depth (all ore) of 134 feet. No. 2 is 100 feet from the last, and struck the trap at 179 feet. No. 3 is 275 feet from the last, and struck the trap at 238 feet.* (See page 510.)

All three holes were started at about the same level, and went through the same stratification of ore, being ranged upon the north and south strike of the ore beds.

The depth of the ore-mass beneath the western branch of Furnace creek, between Middle hill and Grassy hill, is quite as great.

Bore-hole No. 4, 1440 feet S. 76° W. of No. 3, 150 feet from the edge of the Mesozoic red shale, and at a level of 617′ A. T., went down 325 feet, entirely in excellent ore, and without reaching the trap. Whether the ore mass deepens at the Grassy hill end and passes under the Mesozoic covering will be discussed under that head of this report. (See page 510.)

In Big hill, at the north-eastern end, the ore-mass shallows up, because it is completely surrounded by trap; but the depth of ore still remaining beneath the terraces is unknown, although a bore-hole was once drilled to test it, without settling the point.

Bore-hole No. 5, (see map,) was sunk at a point on the flat, 140 feet nearly due east of the railroad bridge over the turnpike, nearly midway between the two trap walls rising to the north and south of it. Its mouth level was about 605′ A. T., and it struck the trap at 50 feet, (555′ A. T.) But there was no knowing on which trap wall, the northern or the southern, the bore-hole stopped.

Now if, as was taken for granted in locating the bore-hole, the two walls meet at this point in the bottom of a basin, it is plain that the ore mass can be only 50 feet deep. But in fact there is no evidence of a basin constructed on this plan. On the contrary, the trap walls are so far off from the hole that if they came together at its bottom their surfaces would have a slope of only about 16°, whereas the

*This bore-hole went down 2 feet further in trap and was then stopped.

northern trap wall has a slant of 38° at a distance 700′ further west, as shown by the line of bore-holes Nos. 1, 2, 3; corresponding to the exposed face of trap in Big, Middle, and Grassy hills, slanting everywhere between 30° and 40°. And the *southern trap wall*, as far as it has been shown by natural exposures or by mining, instead of sloping gently towards the north, stands much steeper, and in some places seems to be going down southwards. If the bore-hole had been put down nearer the south wall it might have gone much deeper in ore. (See page 526.)

Calculation, however, is set at naught by the great irregularities of the surface of the trap in both walls.

A huge shoulder of trap projects some distance from the south wall on the 600-foot level, and has helped to frame the opinion that Big hill is a shallow basin. Two masses of trap project through the floor of ore on the upper terrace, apparently having no connection with the trap walls, although, of course, they must be connected underground. And on the terrace next below, not worked at present, the northern side of the ore mass is studded with such trap knobs, being no doubt irregularities of the northern trap wall.

The Ore-mass in Big hill.

From the Ore Bank Company's railroad bridge crossing the pike, east of the Weigh-house to the eastern wall of trap rock, the ore deposit is about 1400 feet long, and averages about 400′ in width.

The top level or 800′ terrace is about 700×400 feet.

The south side is pretty generally worked down to an 800 foot level, very irregular along the trap wall, owing to frequent shoulders and off-shoots of dolerite protruding from the main body. The north half of this level is composed almost entirely of the soft reddish surface-ore, the present direction of working tending to cut down a 50–60 foot face of this ore to the general level of the terrace. The average shipment from this level amounts to about 60 cars a day.

The ore is readily mined, owing to its soft character, and

HELIOTYPE PRINTING CO., BOSTON, MASS.

UPPER ORE STOPES IN THE CORNWALL MIDDLE HILL, SHOWING THE ORE MASS ABUTTING AGAINST THE UPPER FACE OF THE TRAP AND THE LIMESTONE IN THE HIGH KNOB

requires but little blasting. I saw a good deal of black and brown mica mixed with this ore and some hornblende.

In the second level, just below the one already described, no work was being done. It is here that the trap seems to send out tongues into the ore body, dividing a 50-foot face of ore into four or five parts. These divisions, however, are by no means distinct or absolute, varying considerably in thickness and prominence, and displaying many other irregularities. This feature ceases about 50 feet from the north wall. At the south side of this level the ore is lean, and contains large masses of the greenish soapy gangue rock. Large quantities of this worthless stuff have been used in the construction of sidings outside the ore-body.

The tracks of the third level are designed to carry off the ore mined from a face of ore 120′ high. The aspect of this face is magnificent, and to the traveler approaching the mines from Lebanon by wagon along the pike this superb face of ore is almost the first thing noticed as he emerges from behind the railroad bank through the bridge portal. It must be seen to be appreciated.

Along the north side of the hill the deposit is rather cherty and siliceous, and shows small offshoots of trap of short extension.

The shipments here vary from 1000 to 1500 cars per month, and the work of the drill in this hard ore ranges from 80′ to 150′ per day.

The Robesonia Iron Company mines at present along the south side of this face, carting its ore to the point of the hill and dumping it down to the lowest level. This mining is comparatively expensive.

The fourth level is about 40′ below the last, or 605′ A. T. No work was being carried on there. It shows clearly the wavy structure of the ore and slate in Big hill.

From here to the level of Furnace creek is about 35′, all ore ground, but preserved for railroad tracks, roads, etc.

The ore-mass in Middle hill.

The general appearance of the ore here is most excellent and the Ore Bank Company regard it as the great future sup-

ply store, both on account of the width of the deposit and of its depth as shown by bore-hole No. 4. Very little "No. 1" or fine surface ore remains here, being roughly confined to the 670′ contour line, and fast disappearing.

All the ore, however, has the property of roasting itself; that is, a large percentage of its sulphur disappears after it has been exposed to atmospheric influence for about two years, the action taking effect through a vertical depth of about 3 yards.

The characteristic features of the entire Cornwall deposit can be best studied on this hill, every variety of ore and gangue rock being prominently exposed. The deepest and freshest ore is exposed in the water level cut; but thus far down no appreciable increase in the percentage of iron pyrites takes place; and from the bore-hole samples no increase is to be expected until great depths are reached. In this cut interstratification of ore and gangue rock (a greenish, talcose lime-magnesia slate,) are well seen, (see Photograph plate No. 5,) and the analogy with the occurrence of the ore measures at Wheatfield, Boyertown, etc., established.

About 300′ in the cut there is a barren spot of bastard, slaty limestone, in which there is probably but a very low percentage of iron, resembling closely the "horses" or "wedges" of similar rock found at Warwick and Gabel mines of Boyertown, which oblige the operators there to divide their main entries and carry foot and hanging-wall gangways around on ore.

Beyond this (further west) the face shows successive streaks of ore and gangue from 2 to 6 feet thick, suggesting the original alternate richness and poorness of the pyritiferous lime-shales.

Milky quartz occurred here in the form of a lenticular-shaped mass, probably 2′ wide in the center tapering down at the ends, and 2 feet long, enough to fill a good-sized wheelbarrow. The quartz was embedded entirely in the ore.

A regular quartz conglomerate containing pebbles of white and pink quartz, from the size of a pea to that of a large marble, accompanied with feldspar, and generally hav-

ing a decidedly green cast (due to a greenish silicate mineral, probably chlorite, or some greenish mineral with an equal power of resisting decomposition) occurs between the 650′ and 670′ contour lines, according to Mr. Boyd, in masses weighing from a ton down to smaller sizes, but all surrounded by ore, and without any definite arrangement.

At present but two wedges are sticking up out of the 650′ terrace; but a great quantity of the blasted and broken rock remains on the surface. So far this rock has been met with nowhere else in mining; no rocks in the surrounding hills bear any relation to it in character or composition.

Above and west of this are two limestone knobs surrounded by the soft surface ore, where a good deal of the original surface is undisturbed. (See photograph plate opposite page 511.)

Copper in Middle hill.

On both sides of the hill, along the limestone ridges and knobs, numerous small drifts mark old explorations for copper.

This metal is found in the native state, as a carbonate, as red oxide, but chiefly as a sulphide. It occurs in irregular thin seams, which, traced downwards, always change into the double sulphide of copper and iron, then into iron pyrites entirely. This usually occurs in a distance of from 30 to 40 feet.

Grassy hill.

On *Grassy hill*, owing to the cessation of active mining operations, very little of interest is to be seen.

No break in the south-westward extension of the ore from Middle hill, across the branch of Furnace run, is apparent.

The general appearance of the Grassy hill ore is lean and uninviting now, owing to the presence of much wash and a large mass of decomposed slaty *limestone clay*, which covers more than one half of the present excavation, extending from the railroad track south to the red sand wash.

Limestone, in place, shows at the switch upon entering the hill and dipping south-west. It is further north than any of the outcrops already mentioned, and its decomposed

STRATIFICATION OF THE CORNWALL ORE MASS IN THE NORTH WALL OF THE DEEP ORE CUT MIDDLE HILL

Heliotype Printing Co.

Boston, Mass.

soil is in all respects like the buff-colored clay so generally an accompaniment of the valley limonites.

A considerable amount of *red hematite* was mined from this part of the hill; while to the north and west, adjacent to the trap wall, the characteristic greenish black iron ore, slate and shoulders of trap, so common elsewhere, are repeated. The ore has only been taken out from about 70′ from the top of the hill, and no further development is contemplated here until the extension of the railroad through Middle hill. No bore-holes have been drilled here. The idea that the ore shelves up south-westward here, as it does north-eastward in Big hill, has no foundation in fact, and the only argument that could be adduced for it is the fact that the trap wall slants eastward in a steep and irregular manner.

The Stratification of the Ore-mass.

The second point of interest to the eye of the observer, and of the utmost importance to the geologist, is the universal, regular, and apparently horizontal stratification of the whole deposit, in all three hills, exhibited along the faces of the stopes.

It is plain to see that this stratification is original to the formation and antedates its conversion into ore, or, at all events, antedates the development of its present characteristic mineralogical features; for the whole mass consists of thick and thin beds, regularly superimposed upon each other, having been deposited one after another, as in the case of unchanged sedimentary strata, in an almost if not quite horizontal order. (See photograph plate opposite.)

But when this stratification is looked at sidewise, as exposed in the side stopes, and especially in the great cut through the Middle hill (see plate No. 5) a general dip of the ore beds towards the south-west, in almost all parts of the mine, is plainly visible. This general dip of the ore mass from Big hill through Middle hill into Grassy hill and towards the edge of the Mesozoic at the south-west end, amounts to about 5°, in some places being less, and in others as high as 10° or even 12°.

Wherever possible mining operations are directed against the horizontal basset-edges of the beds; by this arrangement heavier and cleaner blasts are secured.

Along the south side of the ore ground, where the limestone beds appear (to be described below,) there is some departure from the general direction and strength of dip, which can be accounted for without much difficulty by a general settling of the whole ore-formation in the process of change from its original condition of sedimentary lime shale beds to its present state of a stratified ore-mass; to which change of character and position the undissolved limestone beds would only partially conform.

The situation of the ore mass in the great limestone valley and surrounded by a formation of lime shales (to be described further on,) would of itself make it probable that it was originally a formation of lime-shales containing more or less magnesia, silica, alumina, and iron pyrites; and the probability is greatly increased by the bedded and laminated stratification; it is converted into certainty by the fact that a considerable thickness of unchanged lime-shale layers, passing upward into solid beds of hard limestone (whitened and semi-crystallized by the same agency which produced the ore mass,) show themselves near the southern side of the Middle hill mine, in the body of the ore-mass, which has been quarried on both sides of them, above, and beneath them. These unchanged lime shales at one place are seen resting upon the ore; at another place the limestone beds dip under the ore layers at the same angle, and apparently change gradually into ore.

But besides this interstratification of limestone and lime shales with the ore, there is at one place what can only be regarded as an interstratified layer of sandstone and fine conglomerate.* In stoping down to the first or high terrace of Middle hill a range of blocks of this rock was uncovered which extended through 10 feet of the ore vertically, 100 feet long and 20 feet wide. The blocks fell from the face of the stope one by one, and most of them still lie in a pile

---

* Already described on page 511.

CORNWALL MAGNETIC IRON ORE WORKINGS IN MIDDLE HILL LOOKING WEST

— Y LIMESTONE SUMMITS.

HELIOTYPE PRINTING CO., BOSTON, MASS.

on the floor of the terrace, awaiting the approach of the mining operations from below, when they will all fall to the water level plain. Two of them still remain half embedded in the terrace floor.

These sandstone blocks could get into the ore mass in no known way. They must be part of its original stratification: and their separated and rounded forms can be perhaps explained by reference to similar rocks left standing, with edges rounded by solution, in the great brown hematite mines of the State; for example, that of the Pennsylvania furnace, in Centre county. The original production of such layers, or rather streaks of sand and gravel, in limestone formation No. II is nevertheless one of the most curious and mysterious items of sedimentary geology. But however formed at first, they serve well in evidence that the Cornwall magnetic iron ore mass is as sedimentary a formation as the brown hematite ore masses in other parts of the State, and that it was like them originally a formation of magnesian limestone beds, some thick and hard, others very thin, laminated, soft, and easily acted upon by water.

The magnetic quality of the whole Cornwall ore-mass does not prevent this resemblance to the brown hematite ore masses; for Dr. Genth found minute crystals of magnetic iron in the brown-hematite ore of Centre county; and such might probably be found on very careful search in many mines. He also found that some of the brown-hematite (limonite) had parted with a portion of its water of hydration, and this observation also might be repeated at many mines. Both of these facts indicate the beginnings of a change of the brown-hematite ore bodies from their condition of hydrated peroxide (limonite) towards that condition of anhydrous sesquioxide (magnetite) in which we find the whole body of Cornwall ore to have been already brought.

But the strongest evidence of the original stratification remains to be stated, as follows:

The interstratified limestone beds.

Beds of bluish and white limestone, some of them a fair white marble, crop out at several places in the mine, and in such a manner as to show that they are portions of the formation left in an unchanged condition, while the greater part of it has been converted into a mass of ore. They are interstratified in the ore-mass, and have been left standing in knobs and ridges, while the ore has been mined away around them.

In texture and color they resemble many of the beds of the Lebanon valley quarries and the thin lime-shale beds in the railroad cuts between Cornwall and Lebanon. They must belong to the great limestone formation of the Lebanon valley; and their presence in the ore-mass only serves to prove that the ore-mass is itself as much a part of the valley limestone formation as are the numerous brown hematite ore masses which are mined along the valley.

The principal exhibition of limestone occurs on the southern side of Middle hill. A low ridge of limestone runs along the southern border of the main body of ore, dipping beneath or into it. But the ridge consists of two sets of limestone beds, and ore is mined between them, and also under them, *i. e.*, behind or south of the lower set of lime beds. (See plate on page 516.)

In a line with this range, but 1000 feet from its eastern end, white crystalline limestone is exposed at the south end of Big hill, at the angle of the trap wall, just north of the carpenter shop, partially concealed by the ore piles of the Robesonia Company, so that its dip is obscure, but seems to be towards the south-east.

On the northern side of Middle hill, and at its very top, near the three tongues of trap, two sets of limestone beds crop out, and have been left standing as peaks (125 feet above the railroad level) overlooking the whole mine, and even overlooking the ridge of trap. These lime strata dip southwards into the ore mass, so that ore has been mined above, between, and beneath them; that is, between the lowest set of lime beds and the trap. (See page 502.)

South-west of these peaks and on the great floor of the

mine is another outcrop of white limestone exposed in a low cut at the end of one of the rail tracks. The rock is much broken and no certain dip can be assigned to it. It is in the midst of the ore-mass, 80 feet south of the sloping face of trap, 50 feet above the railroad level on Furnace run, east branch, and 30 feet above the water of the west branch. Whether this limestone exposure is directly continuous with that of the peaks is not plainly shown. It may be another and higher set of beds.

Another exhibition of limestone occurs still further on, where the switch enters Grassy hill. The limestone beds here dip south-west. Their soil is like that of the limestone valley generally. This exposure is so much further north-west than the others that no connection with their strike lines is possible.

These limestone exposures require a more particular description for the better understanding of the ore-mass.

The southern range of limestone in Middle hill has its north-eastern end at the short railroad-cut through which the ore from the western part of Middle hill is brought to the main tracks in the valley of the east branch. This cut is nearly 20 feet deep at its west end, where a little peak of solid limestone beds is left standing, from the top of which a good view of the limestone range and its relationship to the ore mass can be got.

Here the solid beds of white dolomite marble are seen alternating with shaly limestones, without any traces of iron pyrites, capped with some remains of the ore-mass which once covered them, and all dipping north-westward about 30° towards and into the ore-mass, upon the great mine floor or terrace of which the cut opens westward.

This spot is especially important, because the superintendent, Mr. Boyd, informs me that an old drift (after copper ore) was once put in on the north side of the little ridge, 40′ lower down, which was of course expected to strike the limestone beds; instead of which the drift, commenced in solid iron ore, continued in iron ore under the limestone, showing that the limestone beds *lose themselves downwards in the* ore mass, or turn to solid ore. This tradition can-

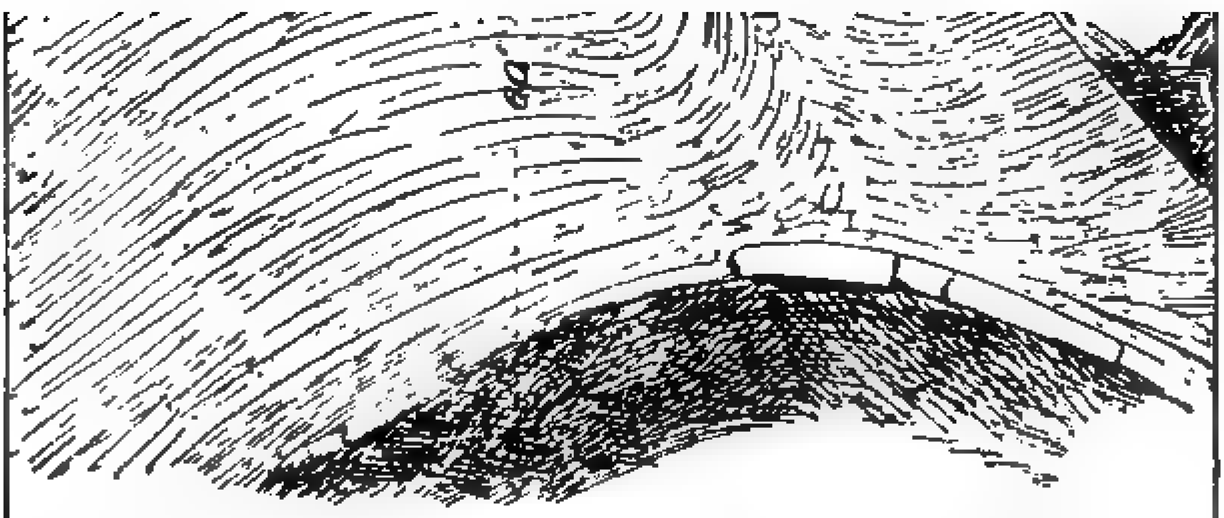
not now be verified; but hereafter in the progress of mining the fact will either be proved or disproved by the laying bare of the south wall of the ore mass.

The little cut opens on to the 620′ A. T. terrace of ore on the west, and is, therefore, 620′ — 575′ = 55′ above the level of the great water plain of ore on the east. The strike of the limestone beds in the cut ought to bring them out upon the water plain, but they do not make their appearance in the ore-mass in that direction. Evidently the limestone beds of the cut do not run on eastward towards the Big hill; and the exposure of limestone near the carpenter shop at the Big hill has no underground connection with the limestone beds of the cut. This is confirmatory of the tradition above mentioned, namely, that the old copper ore search went *under* the limestone in solid ore. It is confirmatory also of the view that the solid limestone beds are lenticular and that the lime-shale beds turn into ore.

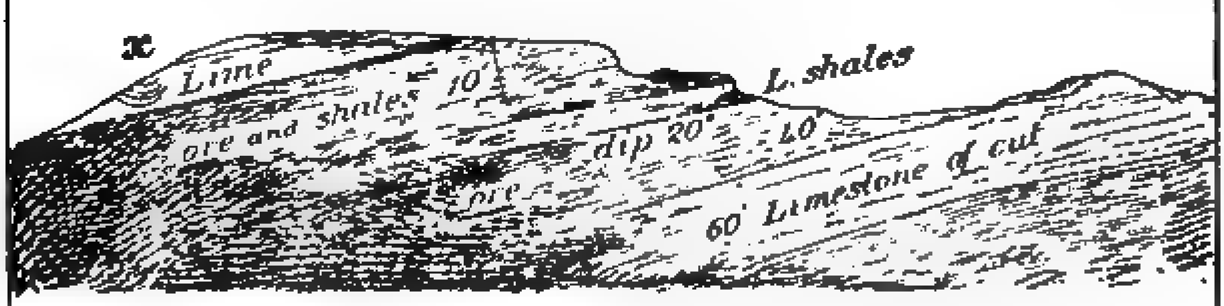
The section of N. W. dipping limestone beds in the cut reads thus:

1. Magnetic iron ore left on the N. W. sloping ends and tops of the side walls of the cut, resting on limestone.	
2. Limestone beds, dolomitic, blue, crystalline,	10′ to 15′
3. Limestone, shaly and greenish shales,	12′
4. Limestone, solid, blue,	8′ to 10′
5. Limestone, slaty, reddish brown,	6′
6. Limestone, massive, white, crystalline (marble,) in two beds,	15′ to 20′

The dip is about 30° towards the north-west, with some curvature and slight crumpling. This north-west direction is transverse to the south-west stratification of the ore-mass of the Middle hill taken as a whole. But it is no evidence of non-conformity; for, in the low south-east border wall, or present stoping ground of the 620′ terrace, white crystalline limestone and lime-shale beds are exposed for 100 feet, with the same north-west dip, and include three distinct ore horizons regularly interstratified with the lime beds dipping in the same direction and at the same angle; showing very plainly that the ore was once lime-shale; and then, overlying these, comes the uppermost principal ore



South side exposures at west end of limestone ridge.



mass, stratified in the same manner and dipping in the same direction.

It is evident, therefore, that the north-west dip merely means that the south border of the whole formation is turned up at a steeper angle; and this is confirmatory of the assertion that the ore-mass as a whole has settled down between its rigid borders into a more or less horizontal generally south-west sloping attitude.

All this is equally well shown in an ore cutting about 800 feet south-west of the little railroad cut just described.

Here a ridge of limestone and lime shales, interstratified with ore, rises to a sharp peak at its west end, about 60 feet high above the 620′ ore terrace. At its east end are projecting lime-shale beds, beneath and on each side of which the ore is mined. The long narrow ridge has been left standing like a wall between the great ore-floor north of it and a deep wide trench of ore south of it. The south side of the ridge shows alternate lime-shales and stratified ore, descending westward at about 10° beneath the massive white limestone which makes its western peak.

Figs. on page 520 show this interstratification, and also the sharp local contortion in the upper solid limestone beds. The shales are here seen turning into ore as they descend westward. The solid limestone layers have remained unchanged, except that they have become crystalline and white.

The interposition of crumpled beds between uncrumpled beds above and below them, here so admirably well exhibited, shows great and irregular lateral pressure, acting possibly before the metamorphosis of the formation into ore, but probably during that process; for it is precisely what we should expect to happen when the more solid portions of the formation, which resisted change, got isolated and enclosed in a slowly moving mass, settling down upon itself as it changed its bulk. Owing to this isolation, it is impossible to affirm with certainty that the lower limestones in this little ridge correspond to the lime beds of the little railroad cut 700′ to the north-east; but if they do not, they

overlie them geologically, so that the top limestones in the peak are still higher beds.

The limestones exposed on the northern border of Middle hill, in the high peaks before mentioned, show the same curious isolation. There is no reason to be assigned why they did not continue north eastward in front of the trap all the way to Big hill; but not a trace of limestone has been encountered in the huge excavation of the water plain and the three upper terraces. The range of limestone, if it be a range westward, stops abruptly at the peaks, and it looks as if the ore will be dug away from beneath them, as well as in front of them and on each side of them.

Figs. on page 502 give sketches of the relation of these peaks to the mine stopes, to each other, and to the tongues of trap in the trap ridge. The sketch serves both for a perspective view and a cross-section, *looking south-west.* The slant of the trap wall varies between 30° and 40°. Ore lies between it and the first limestone, and between the first and second limestone, and to the left of or over the second limestone. The stratification of the ore mass in the stopes and terraces which cross the scene in front of the limestone peaks (which show above them) is apparently horizontal, but in reality at a gentle angle away from the spectator, *i. e.*, south-west.

The limestone beds in the left-hand peak conform to this gentle south-west dip, are 10′ to 15′ thick, are capped with ore on their south slope, and are supported by stratified ore between the peaks.

The limestone beds of the right-hand peak (nearer the trap) are slightly warped upwards, dipping south southwest, and may be 15′ to 20′ thick. Underneath them, and filling the interval of 25′ between them and the trap, lie stratified ore bands, with some talcose magnesian slate.

The limestone of the right-hand peak is very much altered, whitened, crystallized, and charged with copper. The limestone beds of both peaks are quite barren of ore, but porous, pock-marked, and curiously honey-combed. Some Cornwall red lean ore near by, in exactly the same honey-combed condition, is partially changed to a pipe ore,

which a blow-pipe analysis showed to be a manganiferous limonite (brown-hematite.) Better evidence could hardly be desired that even the solid limestone beds of the formation have been partially subjected to the same process which has converted its original lime-shales into the stratified ore-mass of the mine.

The barren limestone ground on the lower ground south-west of the two peaks, at the end of the railroad track, cannot be connected with the limestone beds of the two peaks. The exposure is poor and the rock much altered and cleft in several directions, seeming to dip 30° or 40° southwards, the dip too obscure to give any reliable information.

The stratification of the Cornwall ore formation is thus seen to include wholly or partially decomposed lime shales, and slightly or wholly unchanged solid limestone beds; *i. e.*, unchanged to ore, but altered to marble, made white, crystalline, and brittle, and remaining here and there in the mine as solid strata, sometimes contorted and enclosed between distinct divisions of the ore-mass. In several places the ore is seen replacing the lime rocks or underlying them. As much as 35 feet of solid ore is visible in the face of the trench on the south side of the little limestone ridge on the south side of Middle Hill mine.

The place of the different solid limestones in the stratified series cannot be made out, and they cannot be used as keys to the structure on account of their isolated situations. The notion of an *ore basin* must be abandoned. The old sections drawn on this plan are quite false and misleading. The section accompanying the MS. map of the company was unfortunately constructed on a broken line commencing at the north-east end of Big hill, running along through the middle of the mine through Middle hill, and then turned at a high angle north-west to the summit or the trap border of Grassy hill. This gives it the appearance of a broad shallow basin with inward-sloping trap walls. A section drawn along such a line could not do otherwise than misrepresent the real facts. The longitudinal section given on page 516 shows no such basin shape; and the cross-sections show the ore strata abutting against the sloping wall of the

trap. There was no original basin. The trap has cut diagonally through the originally south-west sloping ore-formation. This is the reason why the limestone beds of the two peaks seem to be near the bottom of the ore mass, because they come so near the trap; whereas they must lie very high in the series, having 500 or 600 feet of ore strata under them; otherwise they would dip south-east and cut all the terraces and stopes down to and beneath the water plain, and would have been cut in bore-holes, Nos. 1, 2, 3. The trap dyke has, therefore, cut its way through all this height of ore strata to get within 20 feet of the limestone of the right-hand peak, and the reason why the limestone has not been encountered in the stopes and terraces east of the two peaks is simply this: that the rise of the stratification north-eastward carries the two series of limestones and intermediate and overlying ore into the air; and, if this be the case, as it certainly must be, then it further follows that the ore strata of Grassy hill are a different and much higher part of the whole formation than the ore strata now being stoped on the eastern side of Middle hill; and any difference in the character of the ores of the two hills can be thus explained.

From this study of the stratification of the Cornwall formation it seems to be a necessary inference that the ore mass is deepest at its south-west end, and that it extends in that direction an unknown distance beneath the Mesozoic country, which seems to cut it off, but which merely buries it beneath a later formation *unless* it be cut off by a line of fault.

It must certainly be conceded that it is *possible* that a line of fault runs along the south edge of the 620 foot level, south of Middle hill, and under the great Mesozoic gravel wash south of Grassy hill. No steps have ever been taken to prove or disprove the existence of such a fault. The ore is, indeed, at one place (back of the limestone ridge) mined up to a bank of red clay in which stratified layers of the Mesozoic shales appear, mouldered and wavy, but in their original places. From this outcrop facing the ore-plain the Mesozoic Dividing ridge rises with a steep wooded slope.

A thick wash of sand and clay and fragments of red sandstone from this hill slope has spread itself over the border of the ore-plain so extensively south of the little west branch of Furnace creek, where the tenant houses stand, that there is good reason to believe that the ore extends at least 400 feet beyond its assumed present limit.

In like manner the southern extension of the Middle and Big hill ore, in the water-plain, up Furnace creek, is concealed by a valley-wash from the Mesozoic Dividing ridge; but here an accident threw light upon the situation. In grading the new C. & L. R. R. to Miners' village, ore was lifted at a point much to the south of the previously admitted limit of ore-ground; and there seems no assignable good reason why the ore should not extend under the whole wash, and under the hill slope to the south—always excepting the possibility of a fault.

But this brings us to the important question: What is the real geological relationship of the stratified ore-mass, with its limestone beds, to the Mesozoic formation which so evidently abuts against it?

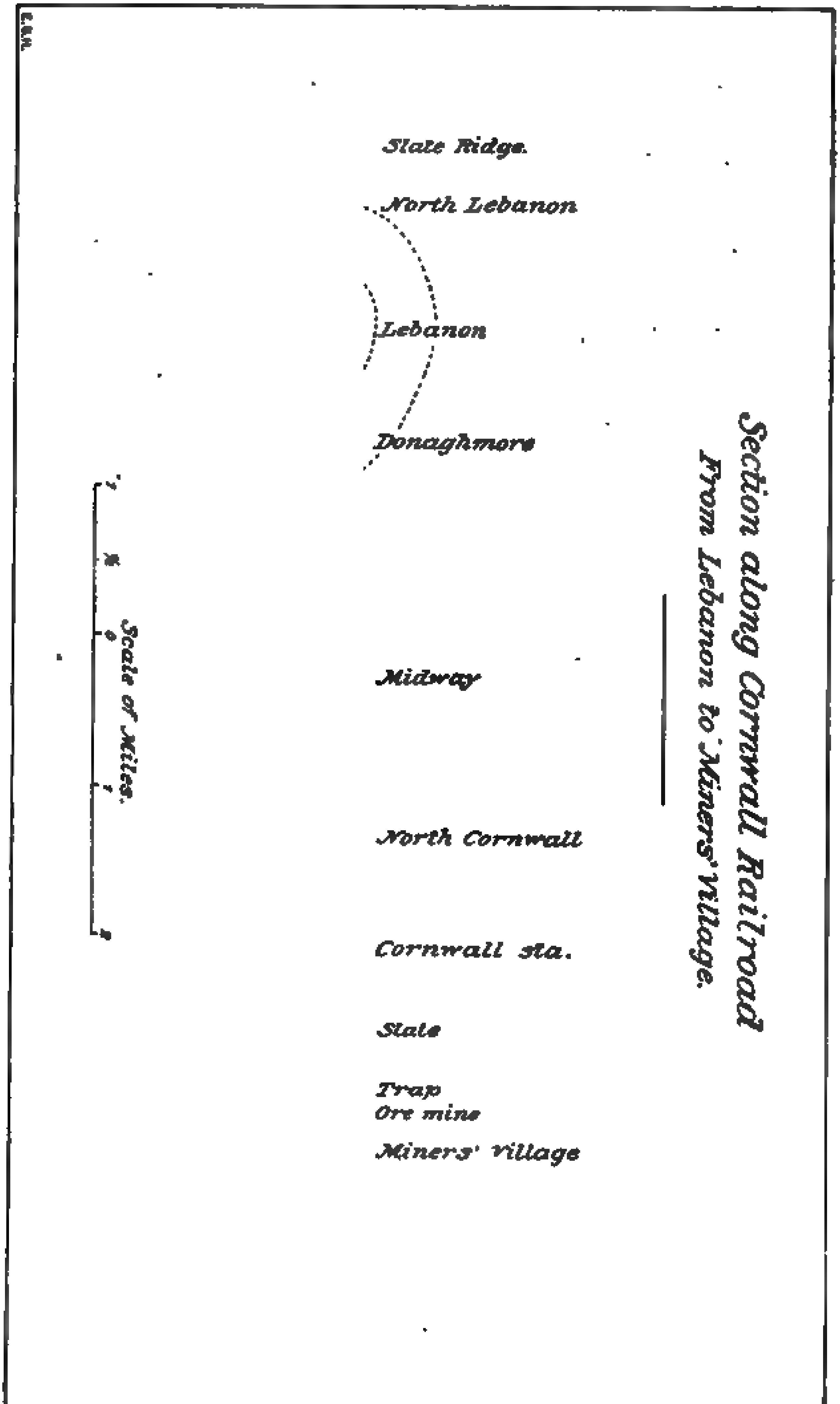
The Mesozoic formation at Cornwall.

At the south base of Big hill important artificial exposures of Mesozoic altered purple-colored clay strata, with slaty texture and filled with decomposed whitish grains of feldspar, have been made all along the Cornwall Ore Bank railroad, from near the carpenter and blacksmith's shop to the engine-house, a distance of about 1000 feet.

These strata dip N. W. at an angle of 15° to 20°; and they are cut, at the carpenter shop, by a trap dyke some yards wide, which represents the south hook of the great trap of Big hill.

At the end of the C. & L. R. R. siding, 350′ south-east of the engine-house, and 400′ south of the miners' houses on the hill above, is another clean exposure of Mesozoic beds, dipping N. W. about 18°, into the hill, thus:

Soil and subsoil, full of red and white quartz pebbles, .	8′ to 10′
Red shale and red sandstone layers, broken, ...	1′ or more
A bed of gray conglomerate, without distinct stratification; pebbles, quartz and some feldspar, ...	5′



Section along Cornwall Railroad
From Lebanon to Miners' Village.

Judging from these almost continuous exposures of New Red strata, and assuming a general dip of 18° to the N. W. (that is into the south slope of Big hill,) there must be about 300 feet thickness of New Red strata in the hill slope, between the exposure in the cut at the end of the R. R. switch and a point in the hill above the miners' houses (on a line with the carpenter's shop) 160′ above water level. These 300 feet of New Red measures must abut against the trap; and therefore the trap dyke must represent a line of downthrow fault.

Along the Cornwall and Mt. Hope railroad, about a quarter of a mile east of the Miners' village, appear beds of Mesozoic sandstone dipping 15°, N. 10° E. (not west,) the exposure being about 6 feet thick; under which lie decomposed shales, 8 feet; under which appears a pebble rock, 3 to 4 feet thick.

Further east (still south of the ore range) two prominent ridges, Sheep hill and Templeman's hill, are made by an outcropping series of Mesozoic altered sand and mud strata, grayish in color and distinctly laminated; said to take a fine polish.

At the south-west end of the mine are similar exhibitions of Mesozoic rocks in place.

The Grassy hill trap (south edge of it) crosses the public road from Cornwall to Mt. Hope close to (100 feet of) where the road crosses the little west branch of Furnace creek. On this road, 200 yards south of the trap, Mesozoic altered pinkish and purple hard broken slates show themselves for a distance of 50 feet, and seem to have a strong N. W. dip.

South of this, and until the road reaches the summit of the Dividing ridge, the whole surface is a wash of pebble, sand, and mud; and this wash stuff covers the slope and low ground south-east and east of Grassy hill all the way past bore-hole No. 4, to the limestone ridge on the south side of Middle hill; and it is under the edge of this wash that the ore *behind* (*i. e.* on the south side of) the limestone ridge seems to lie.

[Here the Mesozoic ridge is made by coarse and fine Mesozoic strata, descending N. W. at a dip of about 17°.

This Mesozoic wash of red sand and gravel, which seems to make a universal covering to the northern slope of the Dividing ridge, consists mostly of loose red sand and rounded pebbles of red quartzite and white quartz. The thickness of the wash varies greatly; in some places it is 10′ thick; at Mr. Grubb's new bore-hole (¾ mile S. W. of Miners' Village) it is reported by the drillers to be 125′ thick.

This bore-hole is the first and only attempt as yet made to explore underground south of the Cornwall ore mine.

Its mouth is on ground 970′± A. T., and its bottom (at present writing) reaches (970′—750′=) 220′ A. T.

Bore-hole No. 3, in the water plain of the ore mine, has its mouth at 570′ A. T. and goes down to (570′—238′=) 332′ A. T.

Assuming a distance of 3600′ and a dip of only 12° from Mr. Grubb's hole to the south edge of the ore mine, the rock at the *top* would descend to (970′—760′=) 210′ A. T., and the last rock struck at the *bottom* of Mr. Grubb's hole would abut against the ore mine at a depth of (750′—210′=) 540′ *below tide;* or, in other words, (540′+332=) 872′ *below the bottom of bore-hole No. 3.*

It is therefore impossible to conceive of any hole drilled on the slopes of the Dividing ridge striking the Cornwall ore mass, however deep it may be drilled; the deeper the worse; for the deeper such a hole goes the further away from the ore it gets.

The dip of the red shale &c. through which the diamond drill descended cannot be distinctly made out either in force or direction. The cores have a diameter of only 1½ inches, and were not drawn up with sufficient precautions against rotation. But there can be no doubt about the north-west direction of the dip, *i. e.* towards the ore mine.

The cores fractured obliquely but not smoothly. One piece from near the bottom, sent by Mr. Grubb for examination, is leveled off at a slope of about 5½ in 24. This indicates a dip of 12°, which agrees with all we know of the general dip of the formation, and may be safely taken as a basis for a calculation such as has been made above.

If the observed dips of 15° and 18° be made the basis of

calculation the result will be the same, and lead still more forcibly to the same conclusion.

It is evident to me that a *downthrow fault* runs along the southern edge of the ore mine; and that many thousand feet of Mesozoic strata are swallowed up by this fault; but it is impossible to draw the line of the fault upon the map until the edge of the ore has been uncovered, for the edge of the ore will necessarily be along the line of the fault.

It is impossible to say at present whether the line of fault is a straight or a crooked line; but the shape of the ground indicates that in Big hill the line of fault follows the south edge of the trap down to the carpenter shop on Furnace creek, and that there a cross fault sets the wall of Mesozoic rocks back to the south. It is evident that the fault must run close south of the limestone ridge of Middle hill, and so on under the wash-ground south of Grassy hill. West of the Mt. Hope road the trap probably takes up the line of fault, but nothing of this can be known until bore-holes are drilled transversely, or until mining operations are extended in this direction.

It is evident that the ore-mass is deepest against the fault, and that it grows deeper westward as it runs along the fault; but whether or not the ore-mass is cut off by the south-bearing trap of Grassy hill coming up to the fault is not apparent; nor can it be safely reasoned on with our present data.

The slant of the fault downwards, if it be not vertical, is quite unknown; if it be vertical, then the ore will have a vertical wall. If it slants southward, as is probable, then the ore mass will practically work down under the overhanging wall of Mesozoic rocks. Where the northern trap, with its slant of 30° to 40°, meets the plane of the fault and descends into it, the ore will stop, and that will be the actual bottom of the ore-mass.

The ore mass may then be looked upon as a lune-shaped fragment of the north wall of the fault, separated from the limestone formation of the valley (to which it belongs) by the trap forsaking in its upward course the plane of fault and tearing through the formation northward; thus isolating the fragment, and enclosing it so that it could become subject

to the ore-forming process. The trap is responsible for the magnetic quality of the ore; for at Hummelstown, in Dauphin county, a similar great ore mass, lying against what must there also be a faulted wall of Mesozoic rocks is not connected with trap, and is not magnetic.*]

The internal constitution of the ore.

When the beds are carefully examined they are seen to differ from ordinary shales and fine sandstone layers in one important particular, their laminæ are minutely rumpled into innumerable creases and fine folds, like a mass of sheets of paper which has been soaked in water and subjected to irregular pressure, and little sections of them are broken and slipped past each other's edges. Almost every block of ore exhibits this internal structure more or less; and the alternation of leaves of light and dark ore makes the fact all the more apparent to the eye; so that many of the large blocks when dressed to a flat surface reminds the observer of dressed slabs of the altered blue marble so much used in Philadelphia. Six such blocks, each intended to be a cubic foot in dimension, have been dressed and placed in two columns of three each, one on each side of the front door of Mr. Boyd's office at the mine; a photograph was taken of the block which represents the leanest grade of ore (24 p. c.) and, therefore, most diversified in its constituents. (See photograph plate opposite page 531.) A sketch was made of the same block but it has not been published.

This internal structure is evidently the effect of a very complicated pressure, produced by a change in the bulk of the mass, due to the removal of some of its constituents by solution. The whole mass settled upon itself as the dissolution went on, and in proportion to the shrinking of all all the leaves of each layer, and of all the layers each one in itself. Hence a universal movement of their parts, in various directions, in the effort to adjust themselves to the smaller space which they had to occupy. What proportion the present bulk of the ore-mass bears to the original

*For the foregoing paragraphs in brackets I am responsible.—J. P. L.

HELIOTYPE PRINTING CO., BOSTON, MASS.

INTERNAL CONSTITUTION OF A BLOCK OF CORNWALL IRON ORE OF LOW GRADE

bulk might be exactly calculated if we knew precisely what the removed elements were, and exactly what percentage of the original mass they constituted.

It can hardly be doubted that the carbonates of lime and magnesia were the principal elements removed from the original mass; and the analyses given below show that there still remains 1 to 5 p. c. of lime, and 1 to 7 p. c. of magnesia in the ore. The lime does not exist in the form of gypsum, although sulphur is present to the extent of ½ to 4 per cent; but in combination with silica and alumina, of which 8 to 21 p. c. of silica and 1 to 8 p. c. of alumina are present in the ore.*

The Chemical Constitution of the Ore.

The first complete analysis of Cornwall ore, made by Mr. A. S. McCreath at the laboratory of the Survey at Harrisburg, shows its chemical constitution, but not its percentage of iron unless taken with his other analyses, made subsequently, of samples gathered by himself for the purpose, in August, 1881.

No. 1. Cornwall "white ore," from the east face of Middle hill; place in the ore mass not stated.

"Cornwall white ore."	*Analysis No. 1.*
Bisulphide of iron,	3.431
Peroxide of iron, } Sesquioxide of iron, }	51.852
Protoxide of manganese,	.371
Oxide of cobalt,	.490
Sulphide of copper,	1.472
Alumina,	2.969
Lime,	9.510
Magnesia,	7.917
Sulphuric acid,	.534
Phosphoric acid,	.038
Carbonic acid,	none

*Dr. Genth says of the brown-hematite ore beds, in Report T4, p. 392: "It is a very remarkable fact that, although these [brown-hematite ore beds of Centre county] are, to a great extent at least, the result of the decomposition of limestones and by them precipitated, that almost the entire amount of lime has been washed out of them, and only traces are remaining; of the second constituent of the limestones, the magnesia, a somewhat larger quantity is left behind, owing, undoubtedly, to the lesser solubility of its carbonate in carbonic acid water."

Water,	1.120
Alkalies and undetermined,	——
Silica,	19.750
	99.454
Metallic iron,	39.600
Metallic manganese,	.288
Metallic copper,	.507
Sulphur,	2.557
Phosphorus,	.017
Phosphorus in 100 parts of iron,	.042

A number of borings of ore for analyses were drilled from each one of the six blocks set up in front of the office of the superintendent, Mr. J. Taylor Boyd, as standard samples of the grades of Cornwall ore. The specimen analysed above would fall under the head of *third grade ore.*

First block, weighing	224 pounds,	first grade,	62 per cent.	iron.
Second "	"	257 "	second "	57 "	"
Third "	"	257 "	second "	55 "	"
Fourth "	"	228 "	third "	44 "	"
Fifth "	"	231 "	third "	42 "	"
Sixth "	"	199 "	fourth "	24 "	"

The blocks were intended to be exactly one cubic foot in contents, but it was impossible to obtain perfectly homogeneous blocks, and the analyses were made by the Company from drillings in the bottoms of the blocks. This accounts for the 44 per cent. ore block weighing less than the 42 per cent. ore block.

The following analyses by Mr. McCreath are arranged in the order of their percentages of metallic iron to show the chemical constitution of the different grades of ore:

Cornwall ore.	*Analyses No. 2.*	*No. 3.*	*No. 4.*	*No. 5.*
Metallic iron,	64.900	57.050	51.450	51.050
Metallic manganese,	.158	.064	.072	.115
Metallic copper,	.005	.447	.559	.295
Alumina,	.324	1.394	1.080	1.289
Lime,	1.010	2.740	2.600	2.340
Magnesia,	1.131	3.942	6.652	6.616
Sulphur,	.071	2.531	2.459	3.271
Phosphorus,	.014	.007	.010	.010
Silica,	3.980	8.650	12.270	11.560
Phosphorus in 100 parts iron,	.021	.012	.019	.019

2. Analysis of 115 pieces of Nigger-head ore from Middle hill.
3. Analysis of "No. 3 ore" from east face of Middle hill.
4. Analysis of fine or soft No. 3 ore from W. cut, N. side, Middle hill.
5. Analysis of fine or soft No. 3 ore from W. cut, S. side, Middle hill.

Cornwall ore.	*Analyses No. 6.*	*No. 7.*	*No. 8.*
Metallic iron,	48.800	46.400	41.900
Metallic manganese,	.057	.238	.194
Metallic copper,	.599	.066	.319
Alumina,	2.315	7.815	4.970
Lime,	4.330	2.550	2.810
Magnesia,	5.531	2.738	7.457
Sulphur,	1.807	.050	.428
Phosphorus,	.018	.023	.019
Silica,	12.940	18.040	20.910
Phosphorus in 100 parts iron,	0.36	.049	.045

6. Analysis of "No. 1 ore" from east face of Middle hill.
7. Analysis of Fix or Wash ore, near engine house, base of Big hill; sam-
pounds.
8. Analysis of "No. 1 light ore" from W. cut, S. face, Middle hill.
he above were dried at 212° F. + before analysis.

omparison of these analyses brings out the prime fact the richness of the ore depends on the percentage of in combination with its three bases, alumina, lime, nagnesia, not at all in equal quantities, but in various ortions of the three. Thus, stated in whole numbers, ave in regular series:

Iron,	65	57	51½	51	49	46½	42	39½
Silica,	4	8½	12½	11½	13	18	21	20
Alumina, Lime, Magnesia,	2½	8	10¼	10¼	12	13	15¼	20½

this we may see an additional evidence of stratifica- the silicates being in the form of a feldspar mud, ged in places with fine quartz sand, the rest of the lime nagnesia being carried off as carbonates in solution by nic acid waters, potash and soda being entirely absent phosphorus in no case reaching *three hundredths* of er cent.

lphur is an important, constant, but very variable con- ent, although so generally distributed through the that the average amount of it per ton must be very y the same for all parts of the ore mass, (except the aal surface of the hills exposed to the long leaching

action of the atmospheric waters,) as an unusually extensive practice has practically demonstrated.

The following additional analyses of car-load samples, made by Mr. Valentine, chemist, and furnished by the Colebrook furnace company, are arranged in the same order of metallic iron:

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)	(8.)	(9.)	(10.)
Iron, . .	57.63	56.16	54.33	52.80	49.04	48.21	45.43	42.86	39.64	36.81
Silica, . .	17.26	14.59	18.67	13.09	17.83	20.68	23.36	23.15	31.45	28.61
Sulphur,	0.11	2.61	0.04	2.05	0.37	0.26	0.03	0.21	1.49	2.58
Copper, .	——	——	——	1.49	1.18	[*2.58]	0.88	0.77	1.17	1.76
Phosphorus,	——	——	——	0.48	trace	——	trace	——	0.06	trace

Nos. 4, 5, 7, 9, 10 were made in December, 1883.—No. 6, from 15 car loads in April, 1884.—Nos. 1, 3, 8, raw surface ore from C. & L. R. R. at entrance to ore hill, August, 1884.—No. 2, November, 1884.

The Cornwall Ore Bank Company are at present mining three grades of ore; the best grade, called No. 1 fine surface ore, yielding from 50 to 55 per cent. iron, being only used to a limited extent as a mixture for fixing puddling furnaces and for small mixtures. The "run of mine" No. 2, mostly a fine or small lump ore, carries from 42 to 50 per cent. of iron, and from 2.5 to 3 per cent. of sulphur. The largest part of the output, No. 3, "select ore," mostly lump ore, carries about 48 per cent. iron, and the same amount of sulphur as the "run of mine" ore.

No. 1 is not roasted, but it is but a small part of the general output. All No. 2 and No. 3 ores are roasted. The following analyses of *roasted* Cornwall ore, made in April, 1880, were furnished by Arthur Brock, Esq., of the North Lebanon furnaces; and they are arranged in the same order of their iron percentage as the preceding.

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)
Iron, ...	57.85	56.78	55.90	55.43	55.35	54.32	52.76
Silica, ...	9.50	10.70	11.85	11.63	11.00	11.30	10.70
Alumina, ...	3.65	4.50	3.80	3.24	4.21	3.70	4.83
Lime, ...	2.12	2.40	2.30	2.06	2.32	2.73	2.86
Magnesia, ...	3.76	4.13	3.52	3.47	4.00	4.31	4.85
Sulphur,†	.45	.40	[.97]	[.42]	.50	[.85]	[.73]
Copper, ...	.37	.31	.29	.30	.53	.30	.34

*Oxide of copper.

†Those in brackets [] are sulphuric acid.

If the silicate bases be taken together, we have:

Alumina, Lime, Magnesia	9.53	11.03	9.62	8.77	10.53	10.74	12.54

The greatest practical difficulty in working the Cornwall ores seems to result from the varying quantity of silica.

An inspection of analyses already presented will show this fact. Sulphur, of course, is hurtful, but the greater portion goes off in roasting.

The presence of copper is likewise objectionable in this ore, as in smelting, it alloys the iron with from 0.75 to 1.25 per cent.

Several manufacturers in different parts of the State, who are consumers of Cornwall ore, have kindly given me the practical results of their experience.

The *Pottsville Iron and Steel Company* use about ¼ to ⅓ of roasted ore in their furnaces, for mixture with cold-short and neutral ores, and with the effect of producing thereby stronger iron.

Their analyses of "run of mines" shipments show from 41.77 per cent. to 49.29 per cent. of iron.

Beaver, Marsh & Co., Union Furnace, Union county, Pa., who have been consumers for 30 years, endorse its value for mixture with the Clinton fossil ores, which are generally all "cold short," and to the improvement of their forge iron. Their experience of "run of mines" ore lately, requires 2½ tons of ore per ton of iron, or a yield of 40 per cent. in furnace working.

The *Chickies Iron Co.*, Chickies, Pa., have used ¼ Cornwall ore in their mixture for some years, the other ¾ being hematite and specular.

They do not roast their ore, using "No. 1" surface ore, which carries a much smaller percentage of sulphur, as already mentioned. Foundry and mill irons made from this mixture rank high.

The Chestnut Hill Iron Co. are also large consumers. The following extracts from a letter of the superintendent, Mr. Jerome L. Boyer's, letter, will prove of interest:

"* * * During my experience at Temple, Birdsboro',

Columbia, and other furnaces, during the last 15 years, have found the ores from Cornwall, Lebanon county, very well adapted as a neutralizer for most hematite ores of the East Penn, Schuylkill, and Susquehanna regions, when roasted to 1 per cent or less in sulphur.

In using 25 per cent. of it in the ore burden, where sulphur runs over 1 per cent., and where copper reaches .90 per cent. (metallic,) the resultant foundry pig is generally lighter in color and closer grained, the fluidity and strength not being affected.

The magnesia in the ore, which reaches sometimes 2.50, and even 3.00 per cent., makes good company for most of the dry limonites, working a hot cinder, and cleaning, without scouring, the crucible and fore-hearth.

The meeting point being considerably lesser than ordinary hematites, it is best adapted for use with hematites after roasting, and, for mill iron, will make least trouble in furnaces if driven fast. The average analysis of many I have had made would show:"

Magnetic oxide of iron,	6?.190%
Oxide of copper,	1.48
Magnesia,	2.69
Lime,	1.11
Phosphoric acid,	0.013
Sulphuric acid,	0.234
Silicic acid,	20.00 to 26.00

Cornwall ore gained high repute in the manufacture of iron nails, imparting at once a stiffness and toughness to the nail much sought after.

Additional light is cast upon the chemical constitution of the Cornwall ore by comparing its analyses with the following analyses of similar magnetic ores from the Boyertown, Reading, and Wheatfield mines in Berks county, and the Dillsburg mines of York county, all similarly situated near the edge of the Mesozoic country; all but the last connected geologically with the underlying older rocks. These analyses are also arranged in the order of their metallic iron percentages, (to the nearest second decimal,) thus:

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)
Iron, . . .	43.40	43.00	42.75	39.60	38.05	34.55
Silica, ...	11.13	14.02	22.10	20.20	16.13	21.21
A. + L. + Mag.,	18 90	13.86	11.45	19.18	19.77	22.38
Copper, ...	.01	.59	——	.12	.56	.17
Manganese, . .	.01	——	——	.23	.42	.21
Sulphur, . . .	.43	.53	.59	1.94	1.14	1.64
Phosphorus, . .	.09	.02	.01	.06	.04	.03

(1.) Black ore, 163 pieces, from Warwick mine, Boyertown, Berks county. A. S. McCreath.

(2.) Magnetic ore from Island mine, Reading, slope No. 1. Leonard Peckitt, Reading.

(3.) Dillsburg ore from A. Underwood's mine. A. S. McCreath.

(4.) Magnetic ore from Wheatfield mine, Berks county.

(5.) Magnetic ore, 25 pounds, from Island mine, Reading. A. S. McCreath.

(6.) "Blue ore," 20 pounds, from Phœnix mines, Boyertown. A. S. McCreath.

The full analyses of Nos. 1, 2, 3, 4, and 6 of the above samples are as follows :

	(1.)	(2.)	(3.)	(4.)	(6.)
Bisulphide, } iron.	.806	.87	1.052	3.58	2.807
Protoxide, } iron.	18.000	17.90	13.930	15.42	14.657
Sesquioxide, } iron.	41.463	41.82	45.640	37.05	31.200
Protoxide of manganese, .	.018	.67	.652	.30	.269
Oxide of cobalt, ...	.010	——	——	——	.030
Sulphide of copper, ...	.012	.99	[.048*]	.15	.251
Alumina, ...	2.407	2.00	1.824	5.90	4.325
Lime, ...	12.980	9.41	5.322	1.90	10.090
Magnesia, ...	3.810	2.45	4.308	11.38	7.963
Sulphuric acid, ...	none.	none.	——	——	.150
Phosphoric acid, ...	.203	.04	.024	.15	.078
Carbonic acid, ...	6.930	10.10	——	2.50	.815
Water, ...	1.285	.85	5.000	1.25	1.500
Alkalies and undet., ...	.946	——	——	——	4.655
Silica, ...	11.130	14.02	22.100	20.20	21.210
	100.000	100.12	99.900	99.78	100.000

If the Cornwall deposit shows any distinctive characteristic when compared with the others, it is in its larger percentage of sulphur, while it shares with the Wheatfield mines a prominence in its copper constituent.

Associated always with a greenish slate, suggesting the presence of chlorite, though mainly made up of the silicates of lime and magnesia, the color of the ore is not the intense

***Oxide of copper.**

black of the azoic magnetites, and hardly intimates its richness.

The hornblendes, augites, micas, steatites, serpentines, and pyroxine, are but a few of the accompanying mineral forms which accompany this ore, and have rendered this locality attractive in the past to the mineralogist. A fairly complete list of the Cornwall minerals may be properly inserted here, but the mines, as the work progresses, seem to produce less wealth of this sort. For the preparation of this list, which will be given later, I am mainly indebted to Dr. F. A. Genth's Report B on the Mineralogy of the State.

The following analyses were communicated to me (Feb. 1, 1886,) by Mr. McCreath; (*a*) being a *greenish-white mineral, free from iron ore*, found in the Cornwall ore, notably in the "white ore;" (*b*) being a similar *greenish mineral* associated with the Dillsburg ore of York county; (*c*) being *limestone* found in the Underwood mine at Dillsburg, not only as nodules in the ore itself, but as a foot-wall to the workings.

	Cornwall.		*Dillsburg.*		
	(*a*)		(*b*)		(*c*)
Silica,	52.11		49.19		14.70
Protoxide of iron,	10.74		5.78		1.32
Alumina,	1.90		5.57		2.99
Lime,	12.54	30.43	22.65	36.27	44.90
Magnesia,	17.89		13.62		3.57
Loss on ignition,	2.03		1.30		31.46
	97.21		98.01		98.94

Mr. McCreath remarks that "in the *limestone* (*c*) calculating all the lime and magnesia to carbonates, it would require 39.20 per cent. of carbonic acid to saturate them. The total loss on ignition is only 31.46; and assuming that all of this is carbonic acid, (with no combined water,) there is a marked deficiency of carbonic acid, showing that some of the lime or magnesia must exist as silicate. Why may not the greenish-white mineral be the residue of beds, or lenticular masses, of such limestone formerly existing in these ores?"

This is precisely the theory of the genesis of the ores

which is given in this report. These beds, for some reason, have resisted solution and remained in the mass, which was wholly constituted of such beds with a difference of constitution such as made them yield to solution and be replaced by ore.

Mr. McCreath subsequently made a determination of the carbonic acid in the limestone (*c*) and found it to be 30.51 per cent.; this would take up 38.83 per cent. of lime; or it it would take up 27.74 per cent. of magnesia. Now, the total lime in the limestone is 44.90, of which the carbonic acid would take up 38.83 and leave 6.07 held as a silicate, (if a simple silicate, with 6.50 silica.) Supposing none of the magnesia (3.57) to be carbonate, it would take 5.35 silica. The 2.99 alumina would neutralize 3.49 silica. Total silica in such supposed silicates, 15.34. Actual silica got by analysis, 14.7. The difference must be due to some of the magnesia being in the condition of carbonate.

It may safely be said that the Cornwall ore mass has experienced three stages of development; being originally a formation of lime shales; then becoming a great brown hematite ore formation; and finally a magnetic ore formation; always retaining its place and general stratification, but becoming consolidated by the loss of most of its lime and magnesia, all its water of crystallization, and part of its oxygen element, and greatly reduced in bulk, without the loss of its original grains of sand, (such as are very visible in the brown hematite ores,) and with a concentration of its percentage of iron.

What that original percentage of iron was is open to conjecture. In some of our brown hematite mines the beds change to carbonate of iron going down below drainage level. In others, cores of sulphuret of iron are found left unchanged in the ore mass. The point of practical importance is that the Cornwall ore mass was part of the sedimentary formations of the Lebanon limestone valley, and was not brought in as a foreign body from a distance, nor ejected as an igneous outburst from the interior of the globe.

It is, however, difficult to ascribe the production of the

Cornwall magnetic ore mass to the dissolving action on lime shales of the common cool running water of the country, which is all we require for an explanation of the brown hematite ore masses of the valley; which also are not in the neighborhood of trap dykes; nor, except in a few cases, near profound faults in the earth's crust; nor, in these few cases, connected with the fault.

But at Cornwall, at Boyertown, at Dillsburg, and elsewhere, the magnetic ore masses are close to trap dykes, and in the general range of the edge of the Mesozoic country. It would be quite reasonable, therefore, to insist on the agency of heat—either dry heat from the lava, or the heat of boiling mineral springs, or the heat of gaseous exhalations—for carrying the ore mass to its third or magnetic stage of development.

Along the north border of the Mesozoic red shale and sandstone country lies an area of lime slates about 4 miles long, about ⅜ of a mile wide at Cornwall, and tapering to a point eastward and westward.* These will be spoken of in this report as the *Cornwall slates*. They hold important relations to the Cornwall ore mass. Their age and order in the Palæozoic system have been much debated, and it cannot be said even now to be determined with absolute certainty whether they underlie or overlie the Lebanon Valley limestone formation; but the balance of probabilities in favor of the view that they *overlie* it has been increasing during the progress of the State Survey, and now seems to me to be very great. The cross section from Lebanon to Cornwall (on page 526) has been constructed independently of any theory, and seems to place the fact almost beyond doubt.

Prof. H. D. Rogers identified these *Cornwall slates* with his *Upper Primal slate*, belonging to formation No. I, overlying the Potsdam (Primal) sandstone, and underlying the Calciferous limestone along the southern edge of the Great Valley all the way from New Jersey to Maryland. He accounted for their apparently overlying the limestone by supposing both formations to be thrown over towards

*See plate on page 492.

the north, so as to bring the bottom beds on top. It cannot be denied that he had good reasons for such a construction in the more complicated parts of the valley; but here in Lebanon county, the limestone formation is unusually free from close plications; the dips are very gentle over considerable areas, as may be seen along the railroad from Lebanon to Womelsdorf, and, although they are almost all southward, *away* from the slates of No. III, yet they probably continue so in Lancaster county under the Mesozoic belt. The one or two rolls in the limestone cuts of the Lebanon-Cornwall railroads do not look like great anticlinal arches, and there is no appearance of overturned dips. Consequently the Cornwall slates may be reasonably looked upon as lying in their original position, *overlying* the limestones, and dipping gently southward.*

If this be so it follows that the Cornwall slates are the same which run through the middle of the Great Valley north of Lebanon and Harrisburg, and are exposed in all the bends of the Conodoguinet creek in Cumberland county, where they make a transition formation between No. II and No. III, consisting of many hundred feet of lime-shales and thin limestones.

At Cornwall these lime-shales are much altered either by pressure or by heat, but they can only be seen in the cut at Cornwall, and in small exposures along Mill ridge, and this is at a distance of nearly half a mile north from the trap in the hill bounding the ore-mass; so that nothing can be said about the rocks in the bed of the little intermediate valley; and therefore nothing is certainly known about the connection of the Cornwall slates north of the trap with the ore mass south of it.

It is important to observe that the Cornwall slates in the railroad cut near the station are hard enough to make a persistent ridge, Mill hill, about 70 feet high, which runs parallel with the trap ridge, at a distance of about 2000 feet, measuring from crest to crest of the two ridges.

This fact seems to intimate that the little valley between

*The fault in the cut at Cornwall will be alluded to hereafter. It seems a small one and is not important.

H.V.L.

1885

hill and the trap ridge is occupied by limestone; but ꞔposures could be found, and no information could be ned from the owners of wells to decide the question, h is a very important one. For, if the little valley be ꞩtone, then Mill hill must either be a synclinal ridge of , or the slate must be cut off by a fault running along outh base of Mill hill; or thirdly, the Mill hill (Corn-) slate is merely a slate formation in the body of the stone formation, No. II, descending southward.

ıe first of these alternatives seems to be the more prob- , first, in view of what can be seen in the railroad cut, secondly, in view of the fact that Mill hill, being only 4 miles long, would naturally have an east and west by erosion if lying in a little basin of limestone.

ıe crumpling of the slates in the cut is easily explained he supposition of a synclinal fold, and the fault, which) beautifully shown in the south-west wall of the cut, ,erely one of the crumples broken, as is plainly proved :he insignificance of the disturbance in the north-east l.

nmediately north of the cut, at Cornwall station, the ey limestones are exposed, with the same 30° to 40° S. dip which the overlying slates at the north end of the exhibit.

n the middle of the cut the slates turn up vertical against under side of the little fault, which slopes about 55° to- :ds the south-west. Then the slates resume their south- ꞩt dip (with very gentle waves) of only 10° or 20°.

)n the north side of the cut the little synclinal is more shed, and the fault is represented by a crushed anti- ıal wave.

[he slates are very rough in appearance, brown in color, l with streaks of quartz. The cleavage planes are ob- ıre, one set seeming to be steep to the north-east.

About half a mile south of the Cornwall "Anthracite :nace," and east along the Mill hill ridge, these slates)p out along the public road, in exposures 4 to 6 feet de, in 25 feet of measures, and appear to dip about N. 18° . 56°, though this may be cleavage. Where the slates

show on the Cornwall and Lebanon pike, where the ridge is cut through by Furnace creek, the dip seems to be N. 12° W. 60°–80°, though wavy and broken. Both these localities are about in the central line of the ridge. South of Eby's Corners (Bismarck) at the junction of the slates and limestones, gray slates dip S. 10° W. 36°, and near the western limit of this main deposit, on the Bachman farm, slates in an old shaft are nearly flat, possibly 5° north.

A very important exposure of these Cornwall slates occurs in South Annville township, about six miles west of Cornwall, in the form of a prominent little ridge on the Long farm, about ¾ miles south of the Horse Shoe turnpike, at Mt. Pleasant. This outlying area of slate is separated, geographically, from the main body around Cornwall by an overlapping projection of the New Red sandstone for a distance of 3 miles, covering the slates.

Here the slates, with the identical characteristics of those at Cornwall, dip 50°–60° to the south-west; and the identity of the formation is confirmed by the fact that a bed of Cornwall magnetic ore occurs in these slates (not over 8′ thick) and has been worked on its outcrop, and by a shaft 25′ deep in the *Carper mine.* The ore apparently occurs entirely within the slate mass and the mine has furnished some 1500 tons.

In the valley, 200 yards north of the Carper mine, several shafts were put down through slate soil, but in every case south-west dipping limestone was found within 15′ of the surface, cropping just north along the course of Kittringer's creek. If these dips represent the true dip and strike of the limestone, they furnish additional evidence of the superposition of the Cornwall slates to the valley limestones.

Returning to the vicinity of Cornwall, the country immediately south of this Mill hill slate ridge, shows a broad flat from 200 to 300 yards wide, watered by branches of Furnace creek, to the base of the ore hills. The soil of this flat is slate, profusely mixed with loose pieces of "nigger head" ore, which have probably been derived from the hills to the south.

tween Cornwall station and Lebanon, the exposures of itones are frequent in the low cuts of the railroads, ıll show south dips, except just south of North Corn- station, where a slight crimple is exhibited, and an- : at North Cornwall station, where a decided and sym- ical low anticlinal arch is visible. From this arch all the to Lebanon city, and beyond the city to the edge of No. III slate country, every exposure of limestone 's a nearly level or a south dip. Those near, or first ı of the arch, are nearly horizontal; then for several ; 5°, 10°, and 20°, and getting up to 50° and 60° as the quarries are approached; and those between the city the slate hills very steep. In spite of numerous con- d intervals, the conclusion arrived at from a general of the whole range of exposures across the limestone . on this transverse line can hardly be other than this, that the gentle wave at North Cornwall station is of rdinate importance, merely interrupting for a moment ;eneral descent of the whole formation from Lebanon ıward towards Cornwall; and, secondly, that a great *urned* anticlinal runs along the valley past Lebanon, at all the steep south dips, there and to the north of it, 'eally carrying the limestones down beneath the slate ation No. III in the hills to the north.

is impossible to locate the upper and lower parts of the stone formation except on general principles established ıe study of it in other parts of the State, because of the nce of fossils; those reported from the Lebanon City ries are concretions and not true fossils. Nor do we get tance from chemical analysis: because the elaborate in- gation of the quarry beds opposite Harrisburg, made ıe Survey in 1877–78, (see Report MM, 1879,) showing 'emarkable alterations of pure limestones with magne- limestones, was necessarily limited to 115 beds, with an egate thickness of 371 feet, which is only a fifth or ı part of the whole formation.

.e Trenton (uppermost) beds are usually free from mag- ı and very fossiliferous in some parts of the Great Val- but they have not been distinctly recognized at Leba-

non, although they ought to outcrop along the edge of the slate hills. But we are not yet certain that the lowest beds of slate No. III, are here conformable with the upper beds of limestone, No. II; and it is possible that the slates overlap them. The dips north of Lebanon being overturned, the slates No. III *seem* to go down beneath the limestones No. II; but all that we know of the two formations in other parts of the Great Valley makes it impossible that the slates No. III should be older and lower than the limestones, No. II; therefore, the beds of both formations must be overturned so as to dip south instead of north.

Minerals found at the Cornwall mines.

1. *Iron Pyrite*, in very complicated and distorted forms. A *cobaltiferous* variety yielded 2 per cent. cobalt (J. M. Blake.) A *cupriferous* variety is also found; tarnishes readily and assumes a steel-blue color, containing (J. C. Booth):

Sulphur,	= 53.37 %
Iron,	= 44.47
Copper,	= 2.89

2. *Chalcopyrite* (Cu_2 S + Fe_2 S_3). Frequently found.

3. *Covelite* (Cu_2 S.) Commercially mined and carrying about 15 per cent. copper.

4. *Cuprite* (Cu_2 O.) Sub-oxide of copper, helping to enrich the poorer copper ores. Occurs on magnetite, in crystalline, finely granulated masses, and beautiful octahedral crystals, sometimes showing cubical and dodecahedral faces, and in fine crimson-red capillary crystals (*chalcotrichite.*) Also in thin coatings upon native copper, giving the latter a dull, somewhat purplish, appearance.

5. *Foliated micaceous hematite.* Red hematite has been considerably mined in Grassy hill.

6. A peculiar variety of magnetite in foliated masses, perhaps pseudomorphs after hematite, frequently interlaminated with pyrite. (Report B, page 39.)

7. *Hydrocuprite*, in peculiar orange-colored coatings, associated with cuprite and magnetite from Big hill. Amorphous, orange-yellow to orange-red; forms very thin; sometimes rag-like coatings on magnetite; soft. (B 46.)

8. *Wad.* A soft black mineral which is dull, but when cut becomes shiny and of a somewhat waxy luster, and is rarely found imbedded in *chrysocalla* ; contains magnetic oxide, cobaltous oxide, and cupric oxide in the ratio of 70: 40: 44. It may be a cobaltous *crednerite.* (B 54.)

9. *Chalcedony.* A pisolitic variety. (B 59.)

10. A variety of "pseudomorphous quartz," in flat rhombohedral crystals, but also in hexagonal prisms. (B 61.)

11. The common *opal* (rarely) in small masses of a grayish, greenish, and yellowish-white color, and vitreous luster, inclining to resinous. (B 61.)

12. *Byssolite.* A variety of actinolite, in very fine globular crystalline nodules radiating from a center. (B 68.)

13. *Vesuvianite.* In imperfect crystalline masses. (B 78.)

14. *Chrysocalla.* In various shades between blue and green, sometimes blackish-green color, and also as pseudomorphs after dolomite. (B 105.)

15. *Allophane.* In very fine white and sky-blue mammillary and stalactitic masses ; a hydrous silicate of alumina. (B. 107.)

16. *Serpentine.* Common variety. (B 115.)

17. *Bieberite.* Rare, a hydrous silicate of cobalt, in minute quantity, as a flesh-colored crystalline incrustation upon magnetite. (B 149.)

18. *Botryogen.* Exceedingly rare hydrous ferroso-ferric sulphate, in microscopic, globular, crystalline aggregations of a deep-red color, associated with covellite and pyrite upon magnetite. (B 150.)

19. *Brochanite.* A combination of sulphate and hydrate of copper, in dark emerald and blackish-green acicular crystals and crusts upon magnetite. (B 151.)

20. *Calcite.* White ; also in globular concretions and incrustations ; colored pink by cobalt upon magnetite. (B 154.)

21. *Malachite.* Fibrous and compact. (B 167.)

22. *Azurite.* In very fine crystals, sometimes over a quarter of an inch in length, and groups of crystals upon

crystalline crusts; usually of dark, but sometimes of pale azure-blue color. (B 168.)

23. *Pyroxene.* Variety, *Mussite;* in minute white crystals; associated with magnetite. (B 65.)

24. *Gypsum* (rare). In beautiful slender crystals, sometimes two inches in length and less than one-eighth of an inch in width. (B 148.)

25. *Rhodochrosite.* A calciferous variety of carbonate of manganese, occurring in globular concretions in cobaltiferous wad. (B 161.)

The Copper in the Cornwall Ore.

Copper.—The intimate association of copper, native, as sulphide, oxide, or carbonate, with the Cornwall iron ore deposit is remarked in several places in this report. No analysis of the ore is free from it.

Commercially considered, however, this ingredient has played its role in the past, the amount prepared at the mines at present being very insignificant.

It is roughly estimated, however, that up to date about 8000 tons of copper, mostly sulphurets, have been produced.

From January 1, 1859, to January 31, 1864, the statement of R. & G. D. Coleman shows the following amount and price of copper ore from Cornwall:

YEAR.	Tons. 2240 lbs.	2352 lbs.		Total amount of sales.	Net amount received.
		T.	Lbs.		
1859, ...	1062.12	911	1673	$30,954 31	
1860, ...	53.11	48	207	1,590 14	
1861, ...	232.06	185	902	6,517 17	
1862, ...	396.11	351	1717	13,711 27	
1863, ...	390.08	342	1396	13,237 72	
	2135.08	1839	1245	$66,010 61	$26,543 98

Percentage of copper varies from 4.35 to 13.20.

The copper ore was mined under an agreement with Benjamin Blewitt and C. M. Wheatly, the former taking out 911 tons, 1673 lbs.

During the same period, R. W. & W. Coleman sold the following amounts, which shows also charges, price, percentage, etc.

Date.	To whom sold.	Quantity.				Percentage of copper.	Price per ton.	Amount.	Charges. Mining and preparing.
		Tons	Cwt.	Qrs.	Lbs.	Per ct.			
1859.	Baltimore Copper Smelting Company.								
April 13,		59	08	2	08	16.00	$72 00	$4.277 39	
May 25,		60	12	1	11	4.69	19 22	1,170 56	
July 6,		64	05	3	21	6.05	24 20	1,555 69	
August 11.		64	12	0	10	5.75	20 34	1 313 45	
October 11,		64	00	0	08	15 12	60 58	3.377 33	$9,478 87
November 15,		59	14	3	08	8.05	29 40	1 755 35	
1860.									
February 24,		29	06	3	02	12.85	57 53	1 695 71	
May 15,		57	09	3	13	11.45	49 24	2 829 86	
September 20,		58	16	1	14	11.40	43 66	2.566 33	
1861.									3 809 47
March 23,	Bergen Copper Co.	67	07	3	12	12 41	43 44	2,926 73	
July 23,		74	09	2	00	12.45	42 70	3.185 05	1,795 84
October 1,		57	11	1	10	12 25	49 00	2 819 45	
1862.	Balt. C. S. Co.								
March 31,		74	14	2	13	11.25	54 43¾	3 991 56	2,083 60
July 12,		61	00	1	02	12.80	51 71	3 154 94	
December 1,		73	17	1	16	11.00	53 57	3.954 97	
1863.									3 296 09
March 31,		62	14	1	10	12 35	71.01	4 451 10	
December 7,		76	06	0	00	9.75	46 31¼	3 532 96	2,325 51
		1066	08	0	18			$49,058 43	$22,779 38

From this table we get a very fair idea of what the expense and returns for this class of work were 20 years ago, as well as the character of the ore mined and quantity.

Under date of November 13, 1885, Mr. Boyd informs me that from 1848 to 1885, the total production of copper ores has been about 8170 tons, averaging about 15 per cent. metal. Of this amount, about 2000 tons were carbonates and 500 tons oxide, the rest being classed as sulphides. Some little copper occurs as silicate.

The mining of Cornwall ore.

Until within recent years, the mining of iron ore at Cornwall was carried on under the present system of quarrying stone or loose rock. Each individual shareholder in the ore bank raised ore from his own "mine-hole," loading at first directly on to wagons that were driven into the banks.

and when that method was superseded by railroads in 1853, tracks were laid, upon which the railroad cars were switched to the various parts of the bank.

This systemless method of mining, which precluded the idea of fixing the responsibility for the amount of ore taken by any one individual party, led to endless trouble and litigation, besides paving the way for expensive mining and interference each year that it was pursued.

During the progress of the famous law-suit for damages in the middle of this century, brought about by a claim on the part of R. W. & W. Coleman, owners of $\frac{50}{96}$, that their co-tenants, R. & G. D. Coleman, owners of $\frac{30}{96}$, had mined and carried away more than their share of ore, many interesting facts were brought out in the testimony of the various witnesses called, as to the method and cost of mining, character of ore, etc., all of which are now a matter of court record.

According to these records, Edw. B. and Clement Grubb, neutral parties to the suit, and owners of the remaining $\frac{16}{96}$, deposed in 1850 that the ore banks consisted of "three contiguous hills, forming one continuous deposit of ore, and containing in the survey thereof 108 acres* or thereabouts."

It was during this period that the ore was worked by "mine holes," and "from partitions made on the ground and excavated independently of each other and without interference."

The court undertook to establish the legal rights of all parties concerned, and appointed a master, who took testimony through a series of years, finally deciding in favor of the plaintiffs, on the ground, mainly: that by the agreement of 1787, under which partition was made of other parts of the real estate, it was stipulated that the ore banks and mine hills, together with certain other ores in the vicinity, should *remain* as a tenancy in common, under which it was held that all the parties concerned were mutually obliged to account to each other according to the percentage of their respective shares in the estate.

---

*This presumably refers to the areas within the so-called "Thos. Clark survey."

This worked very well up to 1848, because all the ore mined had been used in the furnaces of the respective owners.

But from 1848 to 1853, (the period in dispute,) large quantities in addition had been sold by some of the defendants, and "many new and very extensive furnaces had been built by all of the part owners, requiring a greatly increased supply of ore, consuming more annually than was used by any furnace, under the old system, in many years."

The account was ordered to be rendered from April 1, 1848, according to the actual value of the ore used or sold, and from that time until the account was taken numerous witnesses were examined from all adjoining parts of the country in the endeavor to determine, by relative valuation, the amount due the plaintiffs. All records and minutes relating to mining at the Cornwall ore banks were offered in testimony by one or the other parties.

A. Wilhelm, in charge of R. W. & W. Coleman's interests, among other facts, testified that the average cost of mining between the years 1851–1859, including mining, powder, master-miner's salary, and loading on wagons or cars, was $16\frac{28}{100}$ cents per ton. He likewise estimated cost of material per ton of iron at Union Canal, Lebanon, at $9.37½, not including limestone, as follows:

Ore, 2 tons, 2 cwt., @ $1.50 and 30 cents freight,	. . . . . =	**$3.78**
Coal, 2 tons, —— @ 2.70	. . . . . =	**5.40**
Limestone, 13 cwt., @ .50	. . . . . =	**.19½**
		$9.37½

The two furnaces at Cornwall were then making from 80 to 82 tons each, per week.

Charles B. Forney, the manager of the G. D. Coleman Lebanon furnaces, testified to making a ton of iron from $2\frac{23}{100}$ tons of ore and $2\frac{55}{100}$ tons of coal. In 14 years, from 1845–1859, the average ore per ton of iron was 2.14 tons; coal, 2.47 tons. and limestone, 1400 pounds. Total average cost of same, $11.17.

J. Taylor Boyd, then superintendent of R. & G. D. Coleman's interests, now general superintendent of the Cornwall Ore Bank Company, stated the average expense

of mining between 1853 and 1859 was 30.62 cents per ton, including all expenses connected with mining, superintendence, making sales, etc., but *exclusive* of commissions. The lowest cost per ton was 22 cents.

During 1853–54 the defendants made several contracts for the supply of ore through a period of years, all at $1 per ton on cars, with a minimum ranging from 2000 to 5000 tons yearly, and a maximum of from 6000 to 40,000 tons, except in the case of one special contract. The other tenants received about $1.50 per ton for their ore.

The master returned his report to the court September 27, 1861, and upon a valuation of ore at from 85 cents to $1.13 per ton, covering the period from April 1, '48, to December 31, '58. Exceptions were filed to the master's report, who, upon further testimony, again submitted his results in November, 1861, with but little better success. A second time it was referred back to the master on three chief points:

1. The value of the ore from 1848 to 1854 as between the Messrs. Coleman and Grubb.

2. The difference in the relative quality and value of the ore mined, used, and sold by the Messrs. Coleman from April 1, '53, to January 1, '59, and

3. The difference in expense of mining by the parties during the same period.

In the testimony that followed we learn from Mr. Wilhelm that the average cost of mining was as follows:

April 1, 1859,-March, 31, 1860, 13.646 cents per ton of 2240 pounds.

April 1, 1860,-March 31, 1861, 18.637 cents per ton of 2240 pounds.

April 1, 1861,-September 30, 1862, 18.637 cents per ton of 2240 pounds.

Mr. Wilhelm credits the increase of the cost of mining, as compared with the period prior to 1859, as being due to expenditures incurred in laying track and in deeper mining.

J. Taylor Boyd, on behalf of the defendants, stated the cost of mining during the same period to be 30.62 cents per ton, but *excluding* railroad construction and other outside

charges, the average would be reduced to 21 or 22 cents, which throws out cost of hauling and litigation.

Charles B. Forney gave interesting testimony, as follows :

In 1852 "mining proper" began at Cornwall and the *first sale* of ore was made. In 1847 it cost 24 cents per ton to mine and load in wagons ; in 1848, 15 cents ; 1849, 14¾ cents ; 1850, 18½ cents, and 1851, 34¾ cents.

The furnaces in 1848, within a radius of 20 miles of Cornwall, were : 1, Cornwall ; 2, Elizabeth ; 3, Colebrook ; 4, Mt. Hope ; 5, Swatara ; 6, Old Reading (now Robesonia, and enjoying the "perpetual ore privilege") ; 7, Manada ; all of which were charcoal furnaces, and 8, the pair of Lebanon furnaces, one built, the other building.

Fifty tons a week was considered a large tonnage at that time, and about 1000–1200 tons yearly an average output.

The apparent inequalities of cost of production, etc., while seemingly conflicting, are really more due to the different methods of book-keeping, and the different opinions held as to what really were "mining charges" than to any essential advantage that one party possessed over another.

Extracts from two tables are here presented which reflect sharply the condition of the iron industry at this time at Cornwall, and while only partly germane, seem nevertheless, to need no apology for their introduction on account of their historical interest ; No. 1 compiled by C. B. Forney, Esq., and No. 2 by J. T. Boyd, Esq., both during the trial.

Table No. 1.

Extract from statement furnished by C. B. Forney for the years 1848-1858.

Year.	Cost of iron at furnace.	Net price of iron at the furnace.	Iron made.	Cost of ore.
			Tons.	
1848,	$13 63	$19 46	7132.04	$1 11
1849,	14 14	18 11	6847.13	1 51
1850,	16 93	15 76½	4450.11	2 31
1851,	19 32	16 46	4501.17	1 86
1852,	23 00	16 80	2199.11	1 83½
1853,	15 60	26 27	6467.04	1 73
1854,	17 76	27 34	7837.06	1 82
1855,	30 61	19 41	1835.15	1 85
1856,	16 17	20 77	7157.00	1 41
1857,	22 33	21 48	4129.10	1 25
1858,	16 59	14 24	5066.00	1 30
	$18 73	$10 62	5238.10	$1 68

Table No. 2.

Mining at Cornwall ore banks.

Year.	Av'age price paid per ton at the mine.	No. of tons mined and shipped.	Average cost of mining per ton.	Average No. men worked.	Daily wages.	Average amount in tons mined and shipped per man per day.
	Cents.		*Cents.*			
1852,	70.81	17,134.08	14.06	15	$0.69	4
1853,	76.25	57,025.15	11.04	30	.69	6
1854,	79.66	63,655.06	13.56	35	.77	$5\frac{8}{10}$
1855,	95.67	33,607.09	17.04	25	.77	$4\frac{3}{10}$
1856,	102.78	82,851.02	20.03	50	1.00	$5\frac{3}{10}$
1857,	102.57	73,406.03	21.02	46	1.00	$5\frac{1}{10}$
1858,	99.07	37,416.08	22.00	26	.90	$4\frac{6}{10}$
1864,	228.00	165,405.00	33.66	90	1.56	$5\frac{8}{10}$
1865,	215.08	103,840.18	38.76	70	1.51	$5\frac{14}{100}$

In his final report, the master valued the ores mined from April 1, 1853, to January 1, 1855, at 75 cents per ton, and from January 1, 1855, to January 1, 1859, at $1 per ton,

both less the cost of mining, all of which was equivalent to $81\frac{8443}{100000}$ cents on 150,037 T., $7\frac{1}{2}$ cwt., from which it can be judged how cheaply ore was mined at that time. The court sustained this report, and awarded damages accordingly, the Supreme Court affirming the decree of the lower court.

From all this litigation, the principals themselves must have seen the wisdom of a more equable and common course, not only as a matter of justice, but also for the common benefit of all parties, and in the interest of an economical, responsible mining system.

Accordingly in 1864, the present incumbent, Mr. J. Taylor Boyd, was appointed Superintendent of the Cornwall Ore Bank Company, who "shall charge the proprietors with the amount of ore delivered to each of them, for his or their own consumption, at the rate per ton of the one-twentieth, less ten per cent., of the value of the pig metal of which Cornwall ore forms an entire or principal part, in the city of Philadelphia, which shall be ascertained, at the end of every three months, by the average price during that period."

This agreement is still preserved, and under the efficient management of Mr. Boyd there seems to be no question as to the success of the movement to reduce mining to one general system, by which plans can be made for the good of all and for the most economical methods for mining the ore. All evidences of the old "mine holes" are fast disappearing as the plans for a systematic development of the whole ore body are advanced. These look to a general extension of a water-level working face east and west from Furnace creek, and working in successive terraces, in advance of each other, while the general system is maintained.

As tending to this end, a water-level open drift is being at present started westward through the Middle hill, which will eventually be led into the (at present) abandoned Grassy hill opening. This is driven well along the south side of the hill, leaving a water-level face to the north, 80 feet high and 400 feet wide.

The general features of this method of working are suffi-

ciently well shown on the map of the ore banks accompanying this report.

The railroad tracks within the mine advance with the mining, the shifting generally being done in the summer or fall. Between the track and the working face, a platform of untouched ground is left from 10 to 25 feet wide and about 6 feet high, for the double purpose of saving the tracks from the injury of falling ore after blasting, and for facility in loading the ore into the cars.

The character of the broken "run of mines" ore is such that it can be as readily loaded as mixed rock and earth, and the workmen are alternately diggers and loaders.

The commercially prepared ore requires sorting on this platform into lump and fine ore; but the *cost* involved in this transfer from the blasted face of ore into the cars is not necessarily much greater than loading so much mixed rock and dirt from an ordinary railroad cut. Skilled mining labor therefore, in these huge open quarries does not enter into the question of expense at all, except in so far as the common miner is required to judge exteriorly as to the grade of ore when assortment is demanded. And even here, if negligent or incapable, a watchful head-miner can correct his error.

In the *Middle hill* three gangs of men are at present employed, two in the water-level faces, a view of which is seen in photo-plate, opposite page 511, and the third in working down the upper terrace to one general plain, alternating between the ridge of mixed ore and limestone on the south and the piece of nearly virgin territory on the north side, almost all of which is thoroughly oxidized and free from sulphur for at least 50 feet.

In the *Big hill* four distinct terraces are shown on the map, though work is only carried on in two levels, the uppermost, and in the high 120′ face, near the bottom.

This latter face presents decidedly the grandest sight at the banks.

A combination of circumstances led to the adoption of plans to work this immense column of ore in one face, but

it hardly seems as economical or advisable as working in smaller terraces.

After a general blast, the injury possible from falling masses weighing tons each; the difficulty and time lost in moving the smaller ones should they be caught anywhere in their descent; the width of platform required to prevent destruction of tracks, and the consequent extra carriage in loading, are only some of the disadvantages that tend to favor a smaller working face. Indeed, were it possible always to lay out mining operations on paper, a 50-foot face would seem to offer the most inducements for rapid, safe, and economical mining. On the south side of this level the Robesonia Iron Company are working independently, according to the terms of their privilege; and inasmuch as they will require* from 1000 to 1500 tons a week to supply their furnace, it is quite probable that the symmetry of mining may be somewhat abridged, and with some slight loss at least to the general economy.

The work on the upper terrace is to reduce everything to an 800′ A. T. level, through a space 650′ long and 400′ wide.

Most of the ore above that level in this hill is the soft brown ore which requires little or no blasting, and can be very quickly and cheaply mined.

In all these operations, the precision, celerity, and I judge economy of the work, is enhanced by the use of compressed air-drills.

The Cornwall drills, six in number, introduced in the fall of 1882, are of the *Ingersoll* type, 3½-inch cylinder hand-feed, 6½-inch stroke.

Its great advantage in the work it is called upon to perform in this deposit lies in the protection given to the cylinder heads by enclosed elastic cushions, preventing a jar or break in case the drilling bit should suddenly penetrate a soft ore or decomposed rock stratum, and so allows the piston to make a full stroke with safety. One of the chief sources of wear in these drills seems to be in the cutting down of these cushions by the dust and fine ore that rise from the hole during the process of drilling.

*Oct. 30. The Robesonia furnace has just been blown in.

Each drill weighs about 345 pounds, and is worked by two men. They approximate 300 blows a minute, and in the Cornwall ore seem capable of making 150–160 feet a day of 10 hours, boring 3-inch holes 5 feet apart and about 12′ deep. Each drill is computed equivalent to the work of about 18 men.

The air for these drills is derived from the Compressor, a well-built plant, situated in the flat of Furnace creek, midway between Big and Middle hills. A 3-inch main iron pipe carries the air to the hills, where it is sub-divided by 2 and 1½-inch pipes, and conducted to the different working faces.

The greatest distance air is carried at Cornwall is about 1800 feet, and in that distance there is said to be only a loss of about 2 pounds pressure.

The *Compressor* is of the duplex form furnished with water-jacketed air cylinders, and also with spray pumps for cooling by injection, which, however, have been detached at Cornwall. The steam cylinders have 20″ diameters; air cylinders, 21″; the stroke of both is 42 inches, and the number of revolutions 60 per minute.

They are presumed to furnish about 1500 cubic feet of air per minute, and are capable of running 20 three-inch drills.

The boilers are of the return tubular type, 3 in number, having a steam drum across the top of the dome, from which the steam is conveyed to the top of the compressing engines.

They are 5′ in diameter, 14′ long, with 90 tubes each. One boiler is usually held in reserve. They consume about 2 tons of anthracite coal per day of 10 hours, and furnish air at about 60 pounds pressure.

The drills are necessarily kept in advance of the work, a series of holes being drilled or plugged ready for charging in various parts of the banks; and herein lies the great usefulness of the air-drill.

Formerly large quantities of the different classes of ores had to be kept in stock at the mines ready for the varying demand that is apt to arise at any time, especially among

furnaces only using a portion of Cornwall ore for mixture.

These ore piles necessarily interfered somewhat with mining operations, and during cold weather, exposed to snow and rain, the freezing together of the masses added considerably to the total expense of shipment. At present an order for a special grade or amount of ore can be filled without any delay, immense quantities of ore being quickly thrown down from already prepared blast-holes. Dynamite is used both for blasting and in breaking up the larger masses of hard ore after being loosened, where they will not yield to an iron wedge. The charge of dynamite varies, according to the nature of the ground, from 5 to 8 pounds per 12′ hole.

A force of about 200 men are employed at present under four head miners, and the output varies from 35,000 to 40,-000 tons per month, or from 7 to 9 tons a day per man, allowing 25 days to the month, and with wages at 13 to 15 cents per hour.

In comparison with table 2, page —, where the average mined and shipped per day was from 4 to 6 tons per man, the work of 1885 shows a gain of from 50 to 75 per cent.

How much of this is due to the introduction of air drills I had no means of finding out; but of their effectiveness, the great increase of production, and their great adaptability to this class of work, there can be no doubt, and it is but fair to presume that their economy has been well established by their 3 years of continuous service at Corn-.ll.

[n continuation of the data furnished in tables 1 and 2, d for comparison with them, the following, table 3, is ‹en from Mr. Boyd's statement in September 1877, and of interest as showing the average price obtained per ton · Cornwall iron ore, sold to sundry parties from the date formation of the Ore Bank Company in February, 1864, wn to December 31, 1876.

Table No. 3.

YEAR.	Ore sold to proprietors. Averaged per ton.	Ore sold to rolling mills. Averaged per ton.	Ore sold to fill contracts. Averaged per ton.	Ore sold to other parties. Averaged per ton.
1864,	$2 32	$6 21-4	$1 01-8	$3 12-1
1865,	1 92	6 08-6	1 00	2 56-4
1866,	1 77-7	6 18-3	1 00	2 68-2
1867,	1 83	5 59-3	1 00	2 58-4
1868,	1 67-7	7 42-8	1 01-2	3 08-3
1869,	2 29-9	7 93-1	1 00	3 58-6
1870,	1 44-2	7 75	1 42-7	3 14-6
1871,	1 58-6	7 72	1 47-1	3 58
1872,	4 29-6	9 26-4	1 89-4	4 95
1873,	3 63-9	8 58-1	1 95-3	5 10-2
1874,	2 51-4	8 21-8	1 78-7	4 76-9
1875,	2 28-3	5 58-6	——	3 75-4
1876,	1 94-9	3 87-9	——	2 85-4

A comparison of the last two columns of this table will show clearly the error of making special contracts for large supplies of ore through a series of years, especially at a fixed price per ton, as was done in this instance.

In table 2, page 554, the third column gives the average cost of mining from 1852 to 1858; from 1859 to 1864, a statement of Messrs. E. and C. B. Grubb gives the following summary of *their* production and costs:

Table No. 4.

YEAR.	Tons.	Cost.	Average cost.
1859-60,	18,630	$3,907.40	$0 21
60-61,	17,503	3,498.25	20
61-62, } 62-63, } 63-64, }	36,651	1,647.57 } 2,392.16 } 6,343.32 }	28$\frac{33}{100}$
Totals,	72,748	$17,788.70	24$\frac{45}{100}$

During the same period, through Mr. A. Wilhelm's testimony, covering the operations of the other co-tenants, the following summary serves to illustrate the results of mining:

Table No. 5.

(*a.*)

	Tons.	Cwt.
Whole quantity used and sold in 1859, ...	44,309	10$\frac{3}{4}$
Whole quantity used and sold in 1860, ...	54,698	03$\frac{1}{2}$
Whole quantity used and sold in 1861, ...	33,077	19$\frac{1}{4}$
Whole quantity used and sold in 1862, ...	60,348	01$\frac{3}{4}$
Whole quantity used and sold in 1863, ...	76,961	01$\frac{3}{4}$
Whole quantity used and sold, January, 1864, . . .	5,475	05$\frac{1}{4}$
$\frac{50}{80}$ of 48,869 tons 10$\frac{3}{4}$ cwt. ore taken to Robesonia from January 1, 1859, to February 1, 1864, ...	30,543	09$\frac{1}{4}$
	305,413	11$\frac{1}{2}$

(*b.*) *Cost of ore raising during same period.*

From April 1, 1859, to March 31, 1860, ...	13.347 cts.	per ton.
From April 1, 1860, to March 31, 1861, ...	12.313	"
From April 1, 1861, to March 31, 1862, ...	13.401	"
From April 1, 1862, to March 31, 1863, ...	15.895	"
From April 1, 1863, to December 31, 1863, . .	25.474	"
From January 1, 1864, to February 1, 1864, . .	31.368	"

In conclusion of this subject, table No. 6 is designed to show the approximate ore tonnage won from this vast deposit from 1740 to July 1, 1885. Of course such a calculation could only be approximate, though through the courtesy of Superintendent Boyd, the records from April 1, 1848, were furnished from the office books and are therefore reliably representative of the last 37 years' mining. From 1740 to 1790, a period of 50 years, an average has been struck of 6000 tons a year, based on the data that there were but three (3) charcoal furnaces using Cornwall ore, each with a yearly capacity of about 1000 or 1200 tons of pig metal, which is taken as equivalent to about 2000 tons each of ore, after making a due allowance for breakage, out of blast, repairs, etc.

From 1790 to 1848, a period of 58 years, the consumption was about 700,000 tons, based on the product of 6 furnaces, all of which used Cornwall ore.

Though the grand total thus computed, *seven million tons*, seems a large one, it hardly begins to convey what the possibilities of this wonderful deposit really are.

The production of 1885, including the amount mined by the Robesonia Furnace Company, was 508,864$\frac{6}{20}$ tons, and was the demand of what may be called an "off year" in

iron. It was the output from only about *one third* the capacity of the present plant, and it is probably within bounds to say that a yearly output at these mines of two million net tons could be readily managed without the slightest interference to the workings or change of mining plans, and that such a supply could be kept up for about 15 years without exhausting the amount of ore *above water-level.*

Table No. 6.

Showing approximate production of iron ore at Cornwall ore banks.

			Tons.
	*From 1740 to 1790, three furnaces, each 2000 tons yearly, =		300,000
	*From 1790 to 1848, six furnaces, each 2000 tons yearly, about =		700,000
	From April 1, 1848, to January 1, 1853, =		173,190.11
	From January 1, 1853, to February 1, 1864, (date of formation of C. O. B. Company,) =		1,351,717.05
Cornwall Ore Bank Company.	1864, (11 months,)	165,915.02	
	1865,	114,802.11	
	1866,	216,659.16	
	1867,	202,755.03	
	1868,	165,848.03	
	1869,	178,428.16	
	1870,	174,407.17	
	1871,	176,054.15	
	1872,	193,317.01	
	1873,	166,782.06	
	1874,	112,429.04	
	1875,	98,924.17	
	1876,	137,901.11	
	1877,	171,588.19	
	1878,	179,299.03	
	1879,	268,488.06	
	1880,	231,172.18	
	1881,	249,050.01	
	1882,	309,680.11	
	1883,	368,148.10	
	1884,	412,319.17	
	1885,	508,864.06	4,802,839.13
	Grand total from 1740 to January 1, 1886, =		7,327.747.09

* Amount estimated.

The history of mining at Cornwall.

The chain of title to this famous property dates from the proprietaries of Pennsylvania, John, Thomas, and William Penn, incorporated in a tract comprising something less than 10,000 acres of land, (really 9,669 acres.)

The proprietaries assigned the land to one Joseph Turner, and he, in turn, to William Allen, A. D. 1732.

Five years later, in 1737, Allen sold 300 acres to Peter Grubb (distinguished from others of the name as "No. 1") for a consideration of £135, and this transfer may be said to designate the Cornwall ore banks property to-day, though the ore mines proper only contain about 63 acres.

Peter Grubb divided his interest in this land into *third* parts, *two thirds* going to his elder son Curtis, and *one third* to Peter Grubb, ("No. 2,") as shown in diagram:

John, Thomas, William Penn.

Assigned to Joseph Turner.

Assigned to William Allen, 1732.

Peter Grubb ("No. 1"), in 1737.
300 acres (Cornwall ore banks property), for £135.*

Curtis Grubb, $\frac{2}{3}$. "No. 1" Peter Grubb, $\frac{1}{3}$.

June 28, 1783, Curtis Grubb assigned to his son, Peter Grubb, Jr., ("No. 3,") *one sixth* of his interest, which one sixth passed into Robert Coleman's hands in May, 1786, Peter and Mary, his wife, however inserting the following clause in the deed of sale: †

---

* Some records place this date at 1734, April 5.

† This constituted the celebrated "ore privilege" clause, the subject of much litigation, and now held by the Robesonia Iron Company, Limited, of Robesonia, Pa.

"Saving and excepting unto the said Peter Grubb, Jr., his heirs and assigns forever, the right, liberty, and privilege, at all times thereafter, of entering upon the premises and of digging, raising, and hauling away a sufficient quantity of iron ore for the supply of any one furnace at the election of Peter Grubb, Jr., his heirs and assigns, at all times hereafter."

This important reservation still holds good, in spite of the fact that the capacity of blast furnaces has been greatly altered, changing a grant of some 2,000 tons yearly to one of at least 35,000 tons.

This Peter Grubb, Jr., died before his father, Curtis, and on the 8th of December, 1785, steps were taken for an amicable partition of land, etc., between Curtis Grubb, Robert Coleman, and Peter Grubb, ("No. 2,") the brother of Curtis.

It was found impossible to adjust valuations in the ore hills proper, for even then the difficulties of dividing consistently this great ore deposit were very manifest. It was about this time that the "Thomas Clark Survey," was made to determine, if possible, the extent of the ore deposit which its lines were supposed to contain.

This same survey has been made the subject for frequent dispute, until finally the Supreme Court has refused to take cognizance of it. No two men, it is so stated, have ever been able to run out its lines alike, or even locate its corners, and, as it was probably run originally by needle courses and primitive methods, this statement is probably correct.

On May 6, 1786, a division was made, as follows not affecting the ore banks, which were to be held in common tenancy: Curtis Grubb, $\frac{3}{6}$; Robert Coleman, $\frac{1}{6}$; Burd and Henry Bates Grubb, $\frac{2}{6}$, the latter being the children of Peter Grubb, "No. 2," whose one third interest they inherited by will proved January 21, 1786. By this agreement "their respective heirs and assigns should have full privilege and liberty of ingress, egress, and regress to and from said (Cornwall) mine hills, and should have free and uninterrupted liberty and power to dig, sink shafts, drive drifts, raise and carry away any ore that may be found to extend

beyond the limits of said (Thomas Clark) surveys, without doing any injury to the iron works or plantation; and it was thereby agreed that the privileges of the waters should be secured in the most ample manner, for the use of the said Curtis Grubb and Robert Coleman, their heirs and assigns forever."

January 12, 1798, Robert Coleman bought Curtis Grubb's $\frac{3}{6}$ interest for £29,100, and, May 4, 1798, Burd Grubb conveyed his share, $\frac{1}{6}$, to Henry Bates Grubb.

May 12, 1798, Henry Bates Grubb sold his half interest ($\frac{1}{6}$) to Robert Coleman, and February 18, 1803, the two latter parties made an agreement of partition, the property being divided into 96 parts, of which Robert Coleman held $\frac{5}{6}$ or $\frac{80}{96}$ and H. B. Grubb $\frac{1}{6}$ or $\frac{16}{96}$.

Robert Coleman died in 1825, and by will of March 8, 1822, conferred on his sons, William Coleman, $\frac{20}{96}$; James Coleman, $\frac{20}{96}$; Edward Coleman, $\frac{20}{96}$; Thomas Burd Coleman, $\frac{20}{96}$.

April 23, 1828, William conveyed to Thomas Burd his share, or $\frac{20}{96}$, and Edward conveyed his share, in equal parts, to James and Thomas Burd, thus leaving the property (1828) partitioned as follows:

James Coleman,	$\frac{30}{96}$
Thomas Burd Coleman,	$\frac{50}{96}$
H. B. Grubb,	$\frac{16}{96}$

The succession of interests from that time will be best shown in table form as follows:

...s in the Cornwall Estate, since 1828.

...rd Coleman, $\frac{83}{96}$. Henry Bates Grubb, $\frac{13}{96}$,

(died, 1831, leaving) died, leaving

Harriet, his widow, and Harriet A., (widow) and

Robert; Geo. Dawson; Ann; Sarah; Harriet
by act of partition, Jan. 19, 1849.

Robert, $\frac{16\frac{1}{2}}{96}$ and Geo. Dawson, $\frac{16\frac{1}{2}}{96}$.

Annie C.; Mary C.; Sarah H.; Isabella; Robert W.; William
by act of partition, Feb., 1848.

Robert W., $\frac{25}{96}$ and William, $\frac{25}{96}$.

Edward B.; Henry C.; Clement; Mary; Sarah; Alfred B.
by act of partition, 1856.

Edward B., $\frac{6\frac{1}{2}}{96}$ and Clement, $\frac{6\frac{1}{2}}{96}$.

Robert Coleman (of Paris) died July, 1878, leaving a son, Robert, $\frac{16\frac{1}{2}}{96}$.

G. Dawson Coleman died September, 1878, leaving widow, Deborah, $\frac{16\frac{1}{2}}{96}$, in trust, for seven children.

Robert W. Coleman died December, 1864, (unmarried,) dividing his $\frac{25}{96}$ into four equal $6\frac{1}{4}$ parts—one to his brother William's children, and the other three $6\frac{1}{4}$ parts to his sisters—Sarah, $\frac{6\frac{1}{4}}{96}$; Mrs. Margaret C. Freeman, $\frac{6\frac{1}{4}}{96}$, and Mrs. A. C. Alden, $\frac{6\frac{1}{4}}{96}$.

William Coleman died 1861, leaving $\frac{25}{96}$, in equal shares, to his children, Robert and Annie who in addition, have each one half of the $\frac{6\frac{1}{4}}{96}$ from Robert M. Coleman.

Edward B. Grubb died July, 1867, leaving $\frac{6\frac{1}{2}}{96}$, in equal shares, to E. B. Grubb, $\frac{1\frac{5}{8}}{96}$; Henry B., $\frac{1\frac{5}{8}}{96}$; C. Ross, $\frac{1\frac{5}{8}}{96}$; Euphemia, $\frac{1\frac{5}{8}}{96}$.

Clement B. Grubb still owns his $\frac{6\frac{1}{2}}{96}$, and the old "ore privilege" of Peter Grubb, Jr., is enjoyed by the Robesonia Iron Company, Limited, consisting of Borie, $\frac{1}{4}$; White, $\frac{1}{4}$; Mrs. Margaret C. Freeman, $\frac{1}{4}$; Sarah Coleman, $\frac{1}{4}$.

The present interests, therefore, are divided as follows (October, 1885):

Robert Coleman, ...	$\frac{12\frac{1}{3}}{96} + \frac{3\frac{1}{3}}{96} = \frac{15\frac{2}{3}}{96}$
Annie Coleman, ...	$\frac{12\frac{1}{3}}{96} + \frac{3\frac{1}{3}}{96} = \frac{15\frac{2}{3}}{96}$
Deborah Coleman, (wife of G. Dawson,) in trust for seven children, . .	$= \frac{16}{96}$
Robert Coleman, (of Paris,)	$= \frac{16}{96}$
Sarah H. Coleman, ...	$= \frac{6\frac{1}{3}}{96}$
Mrs. Margaret C. Freeman, ...	$= \frac{6\frac{1}{3}}{96}$
Mrs. A. C. Alden, ...	$= \frac{6\frac{1}{3}}{96}$
E. B. Grubb, ...	$= \frac{2}{96}$
Henry B. Grubb, ...	$= \frac{2}{96}$
C. Ross Grubb, ...	$= \frac{2}{96}$
Euphemia Grubb, ...	$= \frac{2}{96}$
Clement B. Grubb, ...	$= \frac{2}{96}$
Total, ...	$\frac{96}{96}$

[NOTE. The Dillsburg magnetic ore mines in York county have been referred to several times in the foregoing report on the Cornwall mine; and comparative analyses of Dillsburg ore will be found in it. The resemblance is striking. The presence of copper is very striking. The presence of greenstone trap is equally important. But it must be confessed that very little progress has been made towards a satisfactory geological explanation of the Dillsburg ore beds. Nor do I see how such an explanation can be obtained until mining operations have advanced far beyond their present extent. As yet the Dillsburg ore seems to be confined to the Triassic formation, although there are imperfect and unsatisfactory indications of its connection with the rocks (slates and limestones) of the underlying Palæozoic floor on which the Triassic beds lie.

There are indeed Triassic limestone beds; and they have been quarried in Adams county, south-west of Gettysburg. But it would be hazardous to look upon the Dillsburg magnetic ore beds with their walls of trap as *altered beds of Triassic limestone.*

In advance of any discussion of the Dillsburg mines, in continuation of and to a more satisfactory issue than what may be found published respecting them in the two reports on York and Adams counties (C and C^2) I have thought it well to secure two local maps, by publishing them in the form of two page-plates here at the end of the Cornwall report.—J. P. L.]

Some general considerations respecting the origin and distribution of the Delaware and Chester Kaolin deposits.

By J. P. Lesley.

The striking parallelism of the streams of the kaolin district of Delaware and Chester counties indicates a general regularity of geological structure. Diverging strikes and varying dips, due to local crimplings (both horizontal and vertical,) characterize all our most ancient rock regions; * but however numerous they may be, and however embarrassing to mining operations at the spots where such operations are prosecuted, they scarcely interfere at all with the normal strike and dip of a large district traversed by the outcrops of formations hundreds of feet, as in this case, and sometimes thousands of feet, in thickness.

Such a dominant strike line is indicated on the colored geological map of Delaware county in several ways. For example, a line drawn from Concordville N. 33° E.† across Chester creek, past Howellville, and across Ridley creek towards Edgemont, will most exactly represent the axis of that arm of the Laurentian gneiss area, on each side of which lie the less ancient serpentine-bearing gneiss belts.

A line drawn from Crawford's Kaolin Works in the same N. 33° E. direction, through Glen Mills on Chester creek, and Castle Rock on Crum creek, will represent not only the axis of the Glen Mills belt of less ancient gneiss, but will pass at or near almost all the exposures of serpentine of western Delaware county.

*As good a place as any to study the infinite complications of the schists, both vertical and horizontal, is along Ridley creek, at the Hillsboro' and Rose Valley mills, 3 miles south of Media.

†On the township maps of Birmingham and Concord the strike is more nearly N. 36° E., and there is no deciding between the two.

This N. 33° E. direction also is evidently the principal strike of the serpentine exposures between Chester creek at Lenni and Darby creek in Radnor township.

The excavation at Crawford's Kaolin Works is on the north side of the Bethel Township road, one sixth of a mile west of Naaman's Creek road, and five sixths of a mile east of where the Township Line road strikes the State line, at the head of Concord creek, a mile south of Elam.

There is no other kaolin opening in the neighborhood to indicate the general strike of the kaolinized gneiss belt; but such an indication is afforded by a line of feldspar-rock quarries extending into the State of Delaware in a direction south-west.

A feldspar-rock quarry a few hundred feet west of Elam, in Concord township, is worked by the Brandywine Summit Kaolin Company. The depth of the quarry on the south side is about 50 feet.

No definite structure is visible. The rock is cleaved in several directions. The outcrop has been distinctly traced south-south-westward through the properties of E. Klett, William Johnson, Samuel Russell, Isaac Green, W. Tweddell, James Guthrie, and Samuel Talley, on the township map. Its course is shown upon the sketch map, which is intended to show the relationship of the kaolin and feldspar belts of both counties with the quarries in the State of Delaware. On Mr. Hall's colored county map Dickson's feldspar quarry and Way's feldspar quarry in Delaware are merely indicated, but not located.

The clay at Crawford's is not fine enough for porcelain ware, and is only used for fire-brick. The excavation is small and affords no indication by which the horizontal extent of the clay can be judged of, nor its possible depth. The country around is flat and cultivated, and apparently everywhere covered with ferruginous gravel.

The American Kaolin Works in New Garden township, Chester county, are situated at the head of Broad run, half a mile south of Kaolin P. O., and within half a mile of the Delaware State line. (Report C^4, page 325.)

The abandonment of the original excavation was caused

by a sudden break of water into an exploring shaft which was being sunk in the floor of the quarry. The flooding of the quarry was sudden, and as if from a very large fissure or reservoir underneath.*

The surface of the country through which Broad run flows in a general south-western direction is made up of clay and quartz fragments all the way from Kaolin to Landenberg, *i. e.*, along a wide belt north of the limestone belt. Wherever the rocks in place are visible they dip south-eastward (as if under the limestone belt,) and at such gentle angles that Dr. Frazer averaged the dip at 10°, which would account for the wide distribution of the surface clays.†

Plastic clay is a good puddling material, as is well known. The standing bodies of rain-water at the bottom of all clay mines would of themselves be a sufficient proof of the fact. Such water does not descend in the ordinary way into the earth, but is evaporated into the air. If water should be found flowing beneath the clay mass, it must be water which has descended through the broken country rock on each side of the clay mass, and has in this manner found its way beneath it.‡

*This would be an important fact indicative of structure did the limestone belt of Broad run lie north instead of south of the kaolin. But the limestone outcrops at Brown's on the railroad at the State line, and the limestone outcrops at the quarries where Broad run and Walnut run and White Clay creek come together, all show south-eastern dips of about 30°. The kaolinized feldspathic rocks, therefore, underlie the limestone, and the underground drainage must be through either semi-decomp sed rocks or along fissures, slips, or faults in the same.

†The surface formation has no distinct structural features. It can hardly be a true deposit, or late surface gravel, like the gravels at Walker's (south of Brown's limestone,) just inside the State of Delaware, or like the gravels overlying the kaolin at Crawford's, south of Elam, in Delaware county. It seems to be the mouldered, disintegrated, and slipped outcropping feldspathic rock of the region, the quartz fragments being the broken quartzose layers or veins of a formation the rest of which has been converted into clay. The amorphous character of the mass of kaolin mined by Mr. Spencer must be due then to the sliding down upon the bed-planes southward of the outcrops of a more completely feldspathic member of the series, decomposed to a greater depth than the rest of the formation, taken as a whole; and this would agree with what has been described at the Brandywine, in Bradenburg township, Delaware county.

‡ At the same time we must remember that the most plastic clay is porous to a certain extent, otherwise a wet ball of clay would never dry. This poros-

The present surface-drainage of Broad run has had its south-western direction determined for it by the gently south-east dipping outcrop-belt, the undercutting having been against the basset edge of the limestone formation.

I see in all this clear evidence that the limestone formation (the south-dipping outcrop of which is at the Delaware State line) once covered the whole of New Garden township; *i. e.*, the whole country between the State line belt of limestone quarries on the south and the Avondale-Kennett Square belt of limestone quarries on the north; and that those two lines of actually existing limestone exposures are all that remain of what was once a thick and solid limestone country.

Of course the surface of that country must have been many hundred feet higher than the present one. From age to age rainfall-erosion has been lowering the surface to its present level. The limestone formation became ramified by caverns, the roofs of which kept falling in here and there, leaving sink-holes, open gulfs, finally vales and valleys, until the whole was removed, and the underlying feldspar rocks were laid bare.

When the last series of caverns reached the top of the feldspar rocks, these began to suffer decomposition along strike lines, and their bed-planes and cleavage-planes permitted the decomposition to descend to various depths. The more purely feldspathic layers suffered the most change, and surface-drainage along the edges of the shrinking areas of limestone sculptured the surface of the country into vales, some of which, if not all of them, are the present water channels, like Broad run.

My apology for introducing what may seem mere elementary truths, or pure speculation, into a description of our kaolin belts is the very serious fact that almost all students of geology, especially those who look upon themselves as practical experts, think of the *present surface of the earth* as having remained from the beginning of the

---

ity of clay to water may be shown by covering a lump of dry stone-hard clay with half a dozen clo hs kept well soaked; in a few hours the lump will have become soft enough to be moulded in the hand.

ages *essentially unchanged*, and try to reason out the explanation of facts upon that supposition. It is, however, impossible to comprehend the geology of a region like Delaware county, so long as this idea of a *permanent surface of the earth* obscures the thinker's mind.

As to Middle and Western Pennsylvania, it is easy to see that it has suffered the loss of many thousands of feet of rock formations. An inspection of the map of the South mountain published in the Atlas to Report D^3 will convince any one that the limestone strata of the Lehigh valley once covered those mountains. There is similar evidence for the fact that this limestone formation No. II once covered northern Chester. It still remains in the Chester county valley, but is being gradually worn away. For all the many ages that erosion has been going on it is not to be supposed that southern Chester and Delaware counties remained unaffected; therefore, we cannot avoid looking upon their patches and belts of limestone as remnants of a once continuous covering of the Chester Valley limestone over the whole region.

If we can get a true idea of the slow lowering of the surface of the State through geological ages we can comprehend why the older Laurentian gneiss belts should come to the surface between belts of less ancient micaceous schists holding serpentine and kaolin; just as the conglomerate and red shale come up between anthracite coal basins which were once as continuous as the bituminous coal-field. We can see that kaolin and serpentine are only to be looked for along certain strike lines, or out-cropping belts of such stratified rocks as are of a nature to permit of the generation of these minerals. No plutonic or volcanic forces need be invoked for explaining the serpentine; nor local thermal springs for explaining the best kaolin deposits.

All that has been said above, however, proceeds on the supposition that the limestone quarries in southern Chester county belong to the limestone formation No. II of Chester valley, Lebanon valley and Lancaster county, made white and crystalline or semi-crystalline by a crushing pressure and recementation, as is plainly visible under the microscope.

There are older limestones interbedded with the gneiss on the Brandywine (see Report C^4); but the Kennett and Broad Run limestones may safely be taken for outlying remnants of formation No. II.

These having been deposited upon an ancient, folded, and eroded surface of gneiss, have a strike and a dip of their own, produced by the folding movements of a later date, and in a different direction.

If the kaolin clays be, as they seem to be, merely the decomposed outcrops of highly feldspathic gneiss, their range ought to conform to the general strike of the gneiss rocks, and not to that of the No. II limestone remnants; and conversely, if the limestone outliers strike across the strike of the gneiss, then there can be no connection between the No. II limestone quarries and the kaolin clay pits, and the one is no guide to the other.

The normal strike of the *feldspar* and *kaolin* belts on the Delaware county map is about S. 35° W. And the same strike prevails in Chester also, if the two feldspar quarries in Pennsbury township (one S. 35° W. of the other) belong to a continuous outcrop, or to what was once such.

But the normal strike of the *limestone* belts of this part of Chester county is about S. 75° W.*

It looks as if there really were a complete non-conformability of the No. II limestone upon the older schists.†

The supposed Potsdam rocks are too little understood to permit us to say how their normal strike mediates between the two above-mentioned non-conformable strikes of the limestone above, and of the schists beneath.

Dr. Frazer suggests (in C^4, pages 325, 326,) that the wide spread of the clays of New Garden township into Delaware

* Such is the course of the Chester County or Downingtown Valley; such is the course of London Grove-Red Lion belt of limestone; such is the course of the Chadd's Ford-Norway-Kennett Square-Avondale belt of limestone; and such is the course of the Broad Run limestone belt, on a continuation of which line occurs a limekiln, in the State of Delaware. See colored map of Chester in Report C^4.

† The Kaolin works in the State of Delaware seem to be arranged on the limestone strike, and not on the strike of the schists.

may be explained by the general gentleness of the S. E. dip of the feldspathic rocks of the whole district. It is, however, desirable to discover what relation to this general gentle dip certain very steep dipping rocks bear which intervene between the kaolins of Chester county and those of the State of Delaware, as, for example, the "rotten syenitic rock, with clay, containing quartz," near the corner of Kennett and New Garden townships and the State of Delaware, dipping S. 30° E., 80°.

If the kaolinized rocks are those which next underlie whatever Potsdam sandstone No. I strata may be left in this region, and the limestone No. II strata overlie the Potsdam, we can understand why the great kaolin exposures are sometimes (as in New Garden township, Chester county) near a limestone belt, and why in other cases they occur in neighborhoods where limestones are now unknown, although they once covered the region.

This raises an important question: *Was the former presence of the limestone* (with or without the sandstone) *an essential condition for the kaolinization of the feldspathic rocks?*

I am not aware that this question has ever been raised, yet it has a direct bearing not only on the kaolinization of Delaware and Chester county rocks, but on the whole subject of erosion, or the sculpturing of the surface of the globe. I have taught for many years that the chemical dissolution of the limestones has been the chief cause of the formation of valleys, and consequently of mountains. Appalachian topography is evidently a result of it. But we are dealing just now not with a pile of Palæozoic interbedded limestones, sandstones and shales, but with a supposed contact of Palæozoic limestones non-conformably overlying the old feldspathic schists. The question takes a special shape: *Did the superimposed limestone in the process of its own chemical dissolution furnish chemical re-agents more energetic for decomposing the underlying rocks than any which would have attacked them had the limestone not been there?*

This seemingly transcendental question is an eminently

practical question, and a notable instance can be adduced to show that it is so. I refer to the case of the *demoralized rock* at the west end of the Hoosac tunnel, in western Massachusetts, described and discussed by Dr. T. Sterry Hunt and others.* It is a case in point; for no discussion of the cause of the *demoralization* of the strata *there* can reach I think a satisfactory conclusion, unless it takes into consideration the effect of the chemical solution of the limestone formation which is faulted directly against the demoralized rocks.†

That part of Virginia and North Carolina which lies east of the Blue Ridge is a country of especially deep *demoralization.* I am not aware that any one has connected this with the fact that the demoralized region was once covered by Tertiary strata; as the 600′ A. T. outcrop at Raleigh sufficiently proves. It seems to me evident enough that chemical re-agents generated in the Tertiary and descending to the old eroded surface of the underlying Azoic country, must have attacked it with great energy.

Now, the same effect produced by the energetic reaction of the Cretaceous and Tertiary calcareous sands and marls upon an underlying Azoic surface, must have been produced

---

***Proceedings of American Inst. of Min. Engrs., Oct., 1874; American Journal of Science, Sept., 1883, page 198.**

† Dr. Hunt takes a very broad view of the subject. He argues that the decomposed mass at the tunnel is a mere local remnant of a universal covering of such decomposed stuff which once covered all New England, but was forcibly removed during the Ice Age by the great glacier; and he points for evidence to the fact that in latitudes to which the glacier could not extend, as in eastern Virginia and the Carolinas, the present surface still remains demoralized to the depth of one or two hundred feet.

He points also to the fact that the rocks at the east end of the Hoosac tunnel (four miles distant) are not demoralized at all; and infers that they were so once, but that the decomposed stuff was entirely swept off by the glacier, so that no trace of it remains. The argument would be good if the strata were of the same kind at both ends of the tunnel; but they are not (as the bed of iron ore at the west end of the tunnel is of itself sufficient to show;) but if of different composition their liability to decomposition was different.

As to any decomposed coat common to both the northern and southern areas t is only necessary to point to the fact that there is none such over south-eastern Pennsylvania, over which the northern ice never moved any more than it idid over Virginia.

by the percolation of waters through the limestone formation No. II upon any Azoic surface *once buried beneath it.*

And the same effect must be produced at every locality where a limestone formation is *faulted against* Azoic rocks. Our limonite beds along the foot of the South Mountain can be thus explained. The west end of the Hoosac tunnel belongs to the same category. The *demoralization* has accidentally been exhibited to us at that one point by the railway cutting, but no one can doubt that it extends for miles along the *west* foot-slope of the mountain; that is, along the line of fault between the mountain schists and the valley limestones; and one may safely assume that the real reason why the *east* slope of the mountain shows no such demoralization is not because the stuff has been removed by ice, but because it never existed there; there being on that side of the range no such limestone faulted against the mountain rocks.

That the demoralization at the west end is not local to the railway line may be inferred from the astonishing depth to which the process of rock-decay has gone. In Virginia the depth of the decay is not known to exceed 200 feet anywhere, and usually varies between 50′ and 150′, quite deep enough to make mining difficult and expensive.*

But in the Hoosac tunnel the steep east-dipping strata were found to be *completely softened and decomposed* for a distance of 600′; that is, to a point 200′ vertically beneath the surface, and *partially decomposed* for 400′ further to a point 230′ beneath the surface. Moreover, at 1200′, (300′ beneath the surface,) a bed of brown hematite iron ore was cut through, which is of course an item of the demoralization. The whole mass of demoralized strata consists largely of *kaolin*, into which the feldspar of the gneiss has been changed.

It is evident that decay has penetrated thus exceptionally deep into the west foot of the Hoosac mountain because of a special local combination of three circumstances: (1) A contact of lime strata with feldspar rocks; (2) an open

*See my report on the Titaniferous Iron Ore Belt of North Carolina, March, 1871, in the Proceedings of the American Philosophical Society, Philadelphia.

water-way in the shape of a downthrow fault; (3) a general dip of the Azoic away from said fault, allowing their bed planes and cleavage cracks to be supplied for ages with limestone drainage waters.*

---

* Dr. Hunt remarks, (*American Journal of Science*, September, 1883, page 198:) "It is evident that this great mass of decayed gneiss at the western base of the Hoosac mountain is but a portion of a once wide-spread mantle of similar materials, which has escaped the action that denuded and striated the surface of the other parts of the mountain. The gneiss on the crest of the mountain, 2000 feet above the sea, and on the eastern slope, wherever exposed, presents the rounded surfaces common throughout the region, often marked by glacial striæ and without any appearance of decay."

Dr. Hunt ventures to apply his glacial theory to the kaolin of Berks county, Pa., at Siesholtzville, where a steep dipping granitoid gneiss, completely kaolinized, has been, as he thinks, protected from erosion by an overlying bed of magnetic iron ore; and to the kaolin in Lehigh county, two miles south of Allentown, where a reddish feldspathic rock in a R. R. cut, kaolinized as a whole, contains masses of undecayed gneiss, along continuous bed planes, these being, as he supposes, protected from erosion by a plate of overlying Potsdam sandstone.

But what Dr. Hunt regards as a protection I regard as an agent. The superimposed rock, instead of preserving a portion of the decayed surface elsewere removed, played, as I believe, the principal part in causing the decay. At the Hoosac tunnel there was nothing to protect the tunnel locality against the great glacier, so far as we can now see. But at Bethlehem and Siesholtzville there was no protection even needed, for the front of the ice never reached that far. And how could a nearly vertical iron ore bed protect a footwall of clay against ice erosion, which never threatened it? The fact is the Seisholtzville locality was once covered by No. I, No. II, and probably still higher Palæozoic formations.

In the striking case of granite surfaces of Minnesota, mentioned by C. A. White and N. H. Winchell, (Geology of Iowa, Vol. I:124. Second Annual Report of the Geology of Minnesota, pages 162, 166, 207,) there is no proof that they were kaolined before the Cretaceous measures were deposited upon them. And in the case of the surfaces described by Irving (Transactions of Wisconsin Academy, Vol. III:13. Proceedings of American Institute of Mining Engineers, Vol. VIII:103.) there is no proof that the kaolinization occurred before the Potsdam sandstone was laid down upon them. In both these cases in the West, there remains merely the lower beds of once thick formations. No doubt the decay began when the last eroded granite surface was fixed by submergence; but one can neither deny nor affirm that most of the decay has been accomplished during the erosion—in fact during the last stages of the erosion of the covering rocks; in comparatively recent times; perhaps pre-glacial; perhaps post-glacial times.

Dr. Hunt himself furnishes a convincing proof of the recent date of all such cases of decay, by describing his own and Joseph LeConte's observations of the decay of the feldspathic pebbles in the upper (but not in the lower) layers of the California "blue gravel;" and by giving a chemical explanation, which exactly suits the other cases above mentioned. Nothing can be plainer than that exposed surfaces are not kaolinized to any great extent. They must

In view of all that has been said above, the possible importance of the little limestone outcrop at the National Kaolin Works, described by Mr. Ashburner in his report, becomes manifest.

In Chester county, lines of *sink holes* show underground

---

be covered by later deposits before the agencies of decay can operate energetically.

The confusion of ideas comes, as usual, from regarding the present surface of the country as no other than the past surface. Dr. Hunt takes for granted (and so describes it) that the decay of rocks at the surface has been an ancient event, not only pre-glacial, but very much older. But that is impossible, simply because the surface level of our limestone valleys (to say nothing of others) has been gradually lowered at least 1000 feet since the Connecticut River red sandstone times. (See my discussion of this point in the Proceedings of the American Philosophical Society, Philadelphia, 1872.)

The level of the limestone valley at the mouth of the Hoosac tunnel must have been considerably higher than it is now, even at the time of the great glacier.

I repeat my belief in a general formula that kaolinization of the feldspathic gneiss-outcrops at the present surface cannot have been an ancient event, but a comparatively recent event, because the present outcrop-surface is itself a recent phenomenon. There has been a different outcrop-surface at every stage of every geological age. General erosion has always been lowering all parts of the earth's surface towards the level of the sea. The special erosion effected by ice during the glacial age was but a fraction of the total erosion effected since the emergence of the coal.

Kaolinization of feldspathic strata is of course a perpetual chemical operation; but since it can only take effect along certain belts occupied by strata constitutionally disposed to be so acted on chemically, while secular erosion has operated mechanically on all kinds of rocks, and on the surface of all regions nearly to the same degree, it follows that kaolinized outcrops, perpetually renewed, have been perpetually removed; and what kaolin patches now exist can not be merely the escaped part of a once universal covering of the earth's surface; but they must represent an infinite backward series of similar patches, similarly produced, and similarly preserved for a longer or shorter time, each in its turn removed by erosion, and replaced by another at a lower level, on the lowered surface of the earth.

But when we apply such a general formula to special outcrops of upturned feldspathic rocks, it must be modified to suit the conditions of the case. The process of decay goes on, keeping step with the process of erosion. As the surface of the district lowers toward sea level, the depth to which the chemical changes penetrate lowers also and proportionally. The already decayed upper part continues always to act as an efficient covering agency to the lower part, collecting, retaining, and transmitting slowly downwards the re-agents, which produce the effect of decay as far down as the lowest general drainage plane of the neighborhood.

In such special cases, then, the phenomenon of *demoralized rock* is either ancient or modern according to the way it is looked at; but the *demoralized rock* itself, as we now see it, is a recent formation.

ranges of dissolving limestone; the prolongation of the line of sink holes brings the observer to limestone quarries at the surface. (See Report C^4, page 318.)

But sink holes are not known in Delaware county, and therefore we must remain content with the explanation that the decay of the rocks, which has produced the kaolin, has depended on the natural drainage downwards along the bed-planes and cleavage-planes, beneath a long since removed covering of sedimentary strata. That it extended further along the strike lines formerly than it does now is an inference from the fact that when the covering formation was removed, erosion of the azoic rocks began again, and that erosion would slowly remove the kaolinized surface along the belts of previous kaolinization, leaving patches more favorably situated for escaping the effects of erosion.

It is evident also that the depth to which the change of feldspar into kaolin has gone in any locality must bear a fixed relation (1) to the facilities afforded for underground drainage by bed-planes, cleavage-planes, faults, porosity of rock, etc., and (2) to some drainage-level established by the topography of the district: the level of springs, the level of river channels, the bottom limit of cavern systems, &c.* No doubt the waters find their way to various moderate depths beneath the drainage-plane, partly along the bed planes and cleavage-planes, and partly by capillary movement through the solid strata; but it is necessary, for chemical change, that the water should not be stagnant, but in perpetual motion; therefore, almost the whole change must take place above the plane of drainage.

I see no good reason for doubting that the depth of the kaolin clays of Birmingham township, in Delaware county, could be approximately calculated by reference to the levels of the Brandywine river as a limit of issue for the underground drainage. Brandywine Summit railroad station grade is quoted at 273 feet above tide, and Chadd's Ford station on the Brandywine, at 129 feet above tide, on the table of the Phila. & B. C. R. R. (Report N, page 158.) In

*I have treated this subject in my description of the Ducktown copper mines, and in various reports of the Survey.

the table of the Wilmington & Reading R. R., Chadd's Ford station is quoted at 175 feet, and Smith's Bridge station at 209 feet above tide. (Report N. page 47.) The level of the bed of the Brandywine at Smith's bridge, or at the mouth of Beaver creek, I do not know; but it must be something like 100 feet above tide. The difference between 273 feet and 100 feet, 173 feet, will serve as an index to the depth of the underground drainage plane of the kaolin works.

The rate at which the change of feldspar into kaolin goes on is wholly unknown, therefore we have no reliable data for estimating the age of the kaolin of Beaver creek. The process is still going on, but at what rate we know not, nor whether it equals the rate of waste by erosion. We do not know when the process commenced, whether since or be-

The white clay walls of the railroad cuts at Grey's Ferry, plainly exhibit the process of kaolinizing the Philadelphia feldspar rocks. The edge of the Wealden clay beds is probably concealed beneath the Delaware river for a long distance above and below Philadelphia. The Grey's Ferry clays stand as a memorial relic of the materials out of which they were made. The erosion of the river has spared them; and it may be that their escape from erosion, as well as their conversion from rock to clay, is ascribable to a covering of Delaware river higher gravels, some of which remain on the terraces.

Now, if a previously kaolinized surface of the Azoic belt was cleaned off to make the Wealden clay, then we must conclude either that the present local kaolin outcrops were spared at that time, or else they have been slowly reproduced since that time. Has it then required the whole Cretaceous and Tertiary ages to kaolinize the feldspathic rock-outcrops locally to their present depth?

This brings forward the inquiry, Why has the kaolinization of continuous outcrops been local?

It is possible that the question arises from a mistake; is based, in fact, on the practical demands of the pottery and porcelain markets rather than on geological fact. Good kaolin clay is only to be found at a few places, and it seems to be an exceptional product of nature; but, in a geological sense, the best kaolin is only one variety, precious for its color and consistency, in a range of clays which represent every grade of kaolinization of every kind of feldspathic rock. Most varieties of kaolin clays would be rejected by the manufacturer, but they cannot be ignored by the prospector. They are extremely abundant and form the subsoil of entire districts. There is no question respecting their *local* occurrence. Wherever feldspathic rocks crop out above water level they are seen to be more or less kaolinized, and to a greater or less depth according to their constitutional proclivity to decay, and according to a thousand accidental local circumstances of drainage. Every kind of feldspar rock passes into its own kind of clay, and every locality exhibits its own structural peculiarities. The

majority of Azoic strata are kaolinized to a depth of only a few inches or feet from the surface; but single beds or groups of beds are decayed to the extreme depth of the underground drainage-plane, but only along their outcrop strike-lines. Therefore it becomes of the greatest importance to the kaolin industry that the order, super-position, dip, and strike of each and all of the members of the Azoic system should be carefully worked out. But it cannot be concealed that this is a tedious and expensive kind of work.

There is still another general consideration affecting in a practical manner our knowledge of the kaolin deposits, and having a special application to both their quantity and their quality.

The chemical constitution of the various grades of kaolin has been abundantly studied and published; but less is said about the amazingly numerous and complicated and very little understood composition of the *feldspars in the rock* out of which the kaolins have been produced. It is a mysterious part of mineralogy; and it hangs a sort of twilight gloom over the geology of the Azoic rocks.

Mineralogists classify under four heads the numerous varieties of feldspar; but the classification is one of convenience only. Innumerable analyses of *orthoclase*, *albite*, *oligoclase*, and *labradorite* have been made and published with no other result than to show that the feldspar-constituent of any granitoid, gneissoid, or sedimentary rock, is always some uncertain and inconstant combination of *silica* with *alumina*, *potash*, *soda*, *lime*, *magnesia*, *iron*, *baryta* and other bases, not subject to any invariable law of number and form as yet discovered.*

Probably no absolutely normal or typical crystal of *orthoclase*, *albite*, *oligoclase*, or *labradorite* has ever been seen. The terms are ideal. Certainly no feldspar rock can be placed without hesitation under any one of these four heads. It can only be said that such and such a chemical description approaches more or less nearly to such and such

*Dr. Hunt's law of relative gravity or degree of condensation affords a basis for a genuine classification.

an ideal feldspar combination, or in other words falls more or less conveniently under such and such a feldspar heading.

Certain practical distinctions are sufficiently apparent, but these can only be regarded as cases of a wider departure from some empirical classification, rather than as ordinances of nature. Feldspars which contain more potash than others do may be conveniently grouped under the name *orthose* or *orthoclase* (square-splitting) feldspars; those that contain soda in place of potash fall under the name *albite* (white) feldspar; those in which more soda and lime than potash are present, and more soda than lime, may be called *oligoclase* (less easily splitting or brittle) feldspar, while all specimens of the *oligoclase* group which show more lime than soda may conveniently receive the geographical name of *labradorite*, because of the abundance of such feldspars in eastern Canada.

But any extensive table of analyses will show what little scientific value such a classification can claim. Delesse, for example, published an analysis of an *albite* from the Vosges with 12.76 potash, 4.61 magnesia, and no soda at all. On the other hand, Sheerer published an analysis of *orthoclase* showing 8.50 soda, 4.78 lime, and only 1.29 potash. Whatever were the physical properties of these two feldspars, their chemical constitution demanded that the *albite* specimen should have been labeled *orthoclase*, and the *orthoclase* specimen *albite*.

But the physical aspect of a feldspar is no less uncertain a guide to its classification than its chemical analysis. Our highest authority in mineralogy asserts that albite and oligoclase cannot be distinguished from one another by external appearance, (Genth, Report B, page 91.) The difficulty which field mineralogists find in naming the feldspar constituent of outcropping rocks springs from the variability of the elements of composition common to them all. A good example is afforded by Dr. Genth's analysis of the Vanarsdale quarry opalescent "labradorite" (Report B, page 89) given in Report B[3], page 225; chemically the min-

eral is "nearly" an orthoclase; and yet it has the characteristic striation of a triclinic feldspar.*

To judge by the analysis of porcelain clays, it would seem at first sight that they came from the decomposition of the potash (orthoclase) group, and a high authority, M. Regnault, takes that view.†

A large number of analyses of such clays have been published, most of which show a larger quantity of residual potash than of residual soda, lime, or magnesia. For instance, the following analysis of one of the Hockessin clays, Newcastle county, Del., shows 1.64 potash and only 0.27 of soda, 0.39 of magnesia, and no lime.‡

Trucks & Parker washed kaolin.

Silica, combined,	40.72	87.15
Alumina,	34.10	
Water, combined,	12.33	
Silica in the form of grains,		6.50
Potash,	1.64	4.79
Soda,	0.27	
Magnesia,	0.39	
Sesquioxide of iron,	2.49	
Water driven off by heating,		1.35
Total,		99.79

An analysis of a Lancaster county clay, given in Report B, page 119, shows 2.2 potash, 0.7 magnesia, 0.1 lime, and a mere trace of soda.

*For Szabo's test of feldspars by coloration of flame and fusibility, see Proceedings of American Association, 1882.

† Regnault, in his Cours Elementaire, II, page 278, says that kaolin masses often hold small fragments of unaltered feldspar, easily separated in the washing process. He regards all kaolin as essentially a decomposition of common potash feldspar (orthose,) although a part of the potash is often replaced by lime or magnesia. Pure kaolin is nothing but a hydrated silicate of alumina. Whatever potash, soda, lime, magnesia, or iron it may contain are constituents which would have disappeared had the kaolinizing process been carried quite to perfection; which, of course, it never can be in nature. Pure (or fat) clay is eminently plastic, imbibing water perfectly. The more foreign constituents it contains the less plastic it is. With much carbonate of lime it becomes marl. Absolutely pure clay cannot be melted in the hottest furnaces; it remains infusible when mixed with sand; hence its fire-brick quality. But when it contains iron or lime it can be melted into glass.

‡ From Williams' Mineral Resources of the United States, 1883, page 472.

Another, from Chester county, shows 0.77 potash, 0.04 lime, and mere traces of magnesia and soda.

Analyses of kaolin from Chestnut Hill, Lancaster county, and from East Nottingham, Chester county, by Dr. F. A. Genth are as follows:

Kaolins.	*Chestnut Hill.*		*E. Nottingham.*	
Silica,	67.1	93.1	46.34	96.41
Alumina,	20.1		36.32	
Water,	5.9		13.75	
Quartz,				1.10
Orthoclase feldspar,				1.04
Potash,	2.0		0.77	
Lime,	0.1		0.04	
Magnesia,	0.7		trace	
Soda,	trace		trace	
Ferric oxide,	3.9		0.64	
Totals,	100.0		100.00	

In the case of the East Nottingham clay, there seems to be positive proof of the fact that it was made from potash (orthoclase) feldspar rock, since Dr. Genth found in it not only 1.10 per cent. of quartz, but 1.04 per cent. of *ortho clase potash undecomposed.*

Two analyses of the clay mined by the National Kaolin and Fire Brick Works, made by D. J. Blodget Britton, have been furnished me by Mr. H. A. Johns, who says (November 1, 1883,) that they were the only ones that the company had had made; that they were several years old (March 30 and April 29, 1874); and that they were made for the special purpose of learning why at that date "the clay was not up to the usual quality." The analyses, however, taught nothing in this respect, "for they only differed from an earlier analysis in the greater quantity of silica and less quantity of alumina. The clay usually runs about 25 to 35 per cent. alumina, with a corresponding decrease in silica."

Johns' kaolin.

	White clay.	*Yellow clay.*
Silica,	71.02	67.71
Allumina,	19.72	20.53
Water and organic matter,	7.04	7.78
Peroxide of iron,	1.56	3.12
Lime,	.32	.89
Magnesia,	.03	.04
Soda and potash,	.27	.29
Undetermined matter and loss,	.04	.14
Total,	100.00	100.00

In these analyses the potash and soda together are less than the lime, but greater than the magnesia. The almost complete disappearance of the alkalies from the rock-material in the process of decay is here plainly exhibited.

ınt, in his "Chemistry of Mineral Waters," page wise gives the first place in the production of the potash (orthoclase) feldspars; but he adds: be noticed that under ordinary atmospheric con- ›rthoclase appears less liable to change than the ı feldspars, such as albite, oligoclase, and labra- Weathered surfaces of these become covered with ›ft, white, and opaque crust, from decomposition; surfaces of orthoclase under similar conditions erve their hardness and transparency."*

ns pretty certain that kaolin deposits should be ›r along geographical *belts of orthoclase feldspar* ınd such belts are prominent in Delaware county. ıeral sometimes is remarkably well developed. ·ystals of orthoclase, weighing 100 pounds, are ›s found, as at Sharple's and Shoemaker's quar- Providence township, and elsewhere. (See Dr. Report B, 1875, page 93.) Wherever this species ar is the principal ingredient of the rocks, and at time the surface is a porous covering of consider- :kness, with a thick surface soil to furnish an

part of his essay is very interesting and instructive, but leaves the ıestion of the origin of our kaolin deposits, as such, still unex-

abundance of humic and other vegetable acids, there the creation of deep deposits of various grades of kaolin clays has probably taken place.

But, on the other hand, a rock wholly composed of feldspar does not submit itself readily to the process of change; and this may be the true explanation of the different degrees of decomposition of feldspar surfaces alluded to by Dr. Hunt.* The absence of clay along the Elam feldspar belt (above) is a noteworthy case in point.

It seems necessary, therefore, that there should be disseminated through the feldspar-rock small isolated crystals of free silica, or grains and lumps of quartz.† This constitution of the rock facilitates the passage of the decomposing waters; and the process of kaolinization taking place first around the surfaces of the grains and lumps, loosens the whole mass, and makes it more and more permeable, so that the process of change goes on with accelerated speed.

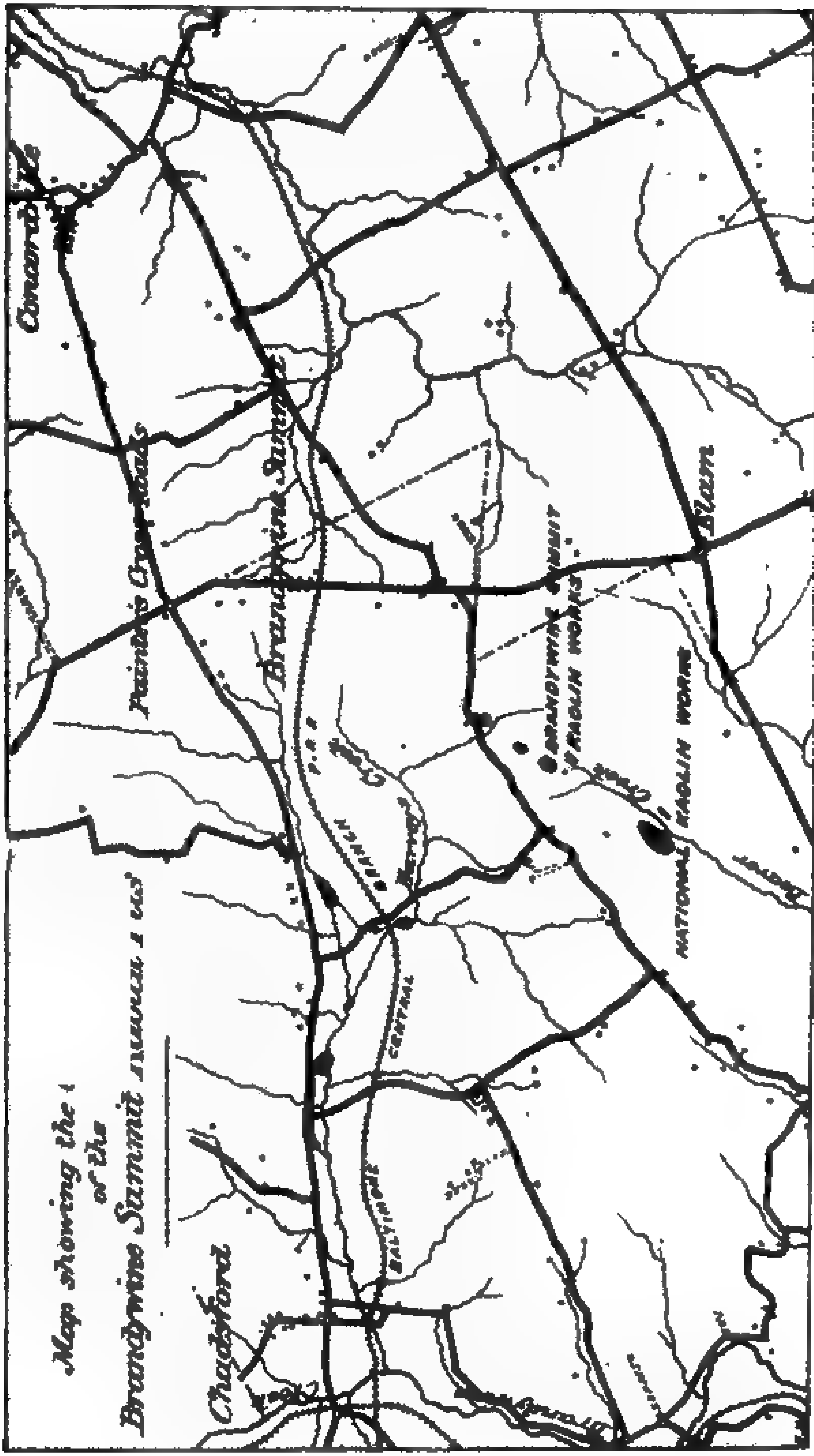
Meanwhile, by the removal of the dissolved ingredients, the original bulk of the strata shrinks and collapses upon itself, settling, and crimpling, and leaving hollows or vales in the geography of the district, which are taken permanent possession of by the rain fall, and thus a river system is established. The depressions will then mainly follow the outcrops of the most favorable strata, and the waterways thus produced increase the supply of soakage.

*On page 99 of "Chemical Essays," Dr. Hunt, after referring to the well known fact that "in the transformation of a feldspar into a kaolin, the double silicate of alumina and alkali takes up a portion of water and is resolved into the hydrous silicate of alumina, while the alkali, together with a definite portion of silica, is separated in a soluble state," confessing that "the preliminary conditions still require investigation," adds, "it is known that, while some feldspathic rocks appear almost unalterable, others containing the same species of feldspar are found converted to a depth of many feet from the surface into kaolin," and quotes Fournet as observing that the change "is always preceded by a mechanical change of the feldspar, which first becomes opaque and friable, and is thus rendered permeable to water. He (Fournet) conceives this alteration to be molecular, and to be connected with the passage of the silicate into a dimorphous or allotropic condition." It is easy to see how the dissemination of free silicic grains through the mass must facilitate the process.

†In Trucks & Parker's clay (above) about $\frac{1}{16}$ of the material consists of silica, in the form of grains of sand.

Pure water is not an agent of chemical change to any extent comparable with waters charged with the acids derived from the air and the soil (ammoniacal, humic, sulphuric, &c.) and acids derived from superficial sand and gravel deposits of recent date. The depressions along the outcrops favor the accumulation of vegetation, receive its products from all sides, and thereby supply re-agents for kaolinizing the rocks.

For an excellent statement of this subject, I refer the reader to Prof. T. C. Chamberlin's chapter on the ore-bearing clays in the last Report on the Geology of Wisconsin, Vol. IV, page 539.



Map showing the
of the
Brandywine Summit
Chadsford
Concord
Painter's Cross Roads
Brandywine Summit
Elam
BRANDYWINE SUMMIT KAOLIN WORKS
NATIONAL KAOLIN WORKS
CENTRAL
BALTIMORE

Report on the Brandywine Summit Kaolin-bed, Delaware county.

By Charles A. Ashburner.

The Brandywine Summit Kaolin-bed, situated in Birmingham township, Delaware county, from one mile to one mile and a half south-west of Brandywine Summit station the Baltimore Central Railroad, has been worked for ny years.

'he oldest and most extensive workings are on the prop- y of the National Kaolin Works, now owned and oper- d by H. A. Johns & Company. These are situated near head-waters of the west branch of Beaver creek.

Vorth-west of the National Kaolin pit the same bed has n more recently worked by the Brandywine Summit olin Works, the property of the John Griffin estate, of ich Mr. W. S. Manley is manager. On the latter prop- y clay has been taken from three pits which have been ned along the bed. The north-eastern pit, (No. 2,) im- diately south of Golding's old clay mill, is the nearest 'elopment of the bed to Brandywine Summit station, the tance being one mile. Pit No. 1, in which the most ex- sive diggings have been made on the Griffin farm, is lated 700 feet south-west of Pit No. 2. Pit No. 3 's the same range and about 400 feet south-west of Pit No.

Pits Nos. 2 and 3 have not been worked for several ırs, since the clay which was obtained from No. 3 is re- ted not to have been as good as the clay which has been ; from Pit No. 1; the clay taken from Pit No. 2 was of etter grade than a great deal of the clay from Pit No. 1, : the proportion of clay to the amount of material re- ved was not as great as at No. 1.

The relative position of the Brandywine pits to the railroad station and other localities is shown on the accompanying plate, (page 592,) and on the general map of the kaolin district of Delaware and Chester counties. The topography of the surface in the vicinity of the clay-pits is shown on the accompanying topographical map constructed from surveys by myself and assistant, Mr. George M. Lehman.

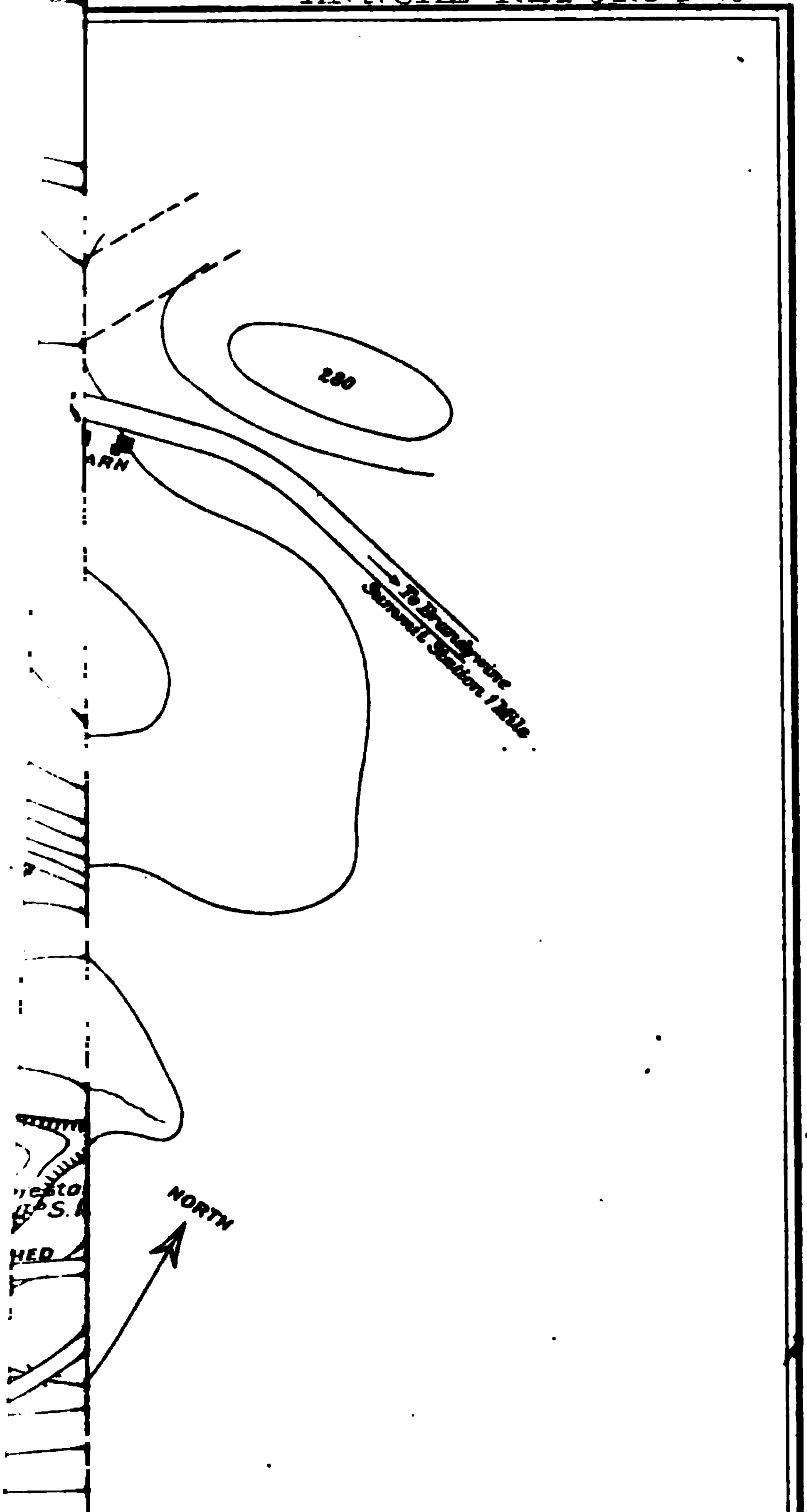
On the Johns farm the clay-bed has been worked in but one pit, the length of which is about 850 feet, and the width a little over 300 feet. These measurements were made from the outside edges of the pit in September, 1885, and they do not represent the area out of which the clay has been dug, since a large amount of loose material has fallen in around the edges of the area out of which the clay has been taken.

During the summer of 1885 I made a practical exploration of the clay-bed, with a view of ascertaining its extent, together with the quality and quantity of commercial clay which was contained in any given portion of the bed. These explorations were made principally on the Griffin farm, while the extent of the developments which have been made on the Johns farm has been such as to permit of sufficient facts being obtained to deduce conclusions as to the above questions, when considered in relation to both properties.

In order to ascertain the depth of a vertical section of the bed, a shaft 3 feet wide and 4 feet 9 inches long was located 45 feet south of the then edge of the Griffin Pit, No. 1, and near what was assumed to be the middle of the bed. The elevation of this shaft is 263* feet above tide, and the depth to which it was sunk was 61 feet 8 inches, work being stopped at the point where the clay was entirely passed through and where undecomposed rock was found. The following is a section of the bed in the shaft:

---

*The elevation of Brandywine Summit station is 273 feet above tide. The elevation of the north-east corner of the Griffen farm was determined by a number of barometric observations between this point and the R. R. station. The elevations on the topographical map were determined instrumentally, based upon this barometric elevation.



Notes.

...sition of the Kaolin bed outlined on this map has been deter...l from the pit workings and prospect holes of H. A. Johns and ...l the John Griffen Estate, in addition to practical explorations ... during the summer of 1885, under the personal direction of ...burner.

...olin bed is decomposed from feldspar and feldspathic rocks ...ratified with the mica shists, gneisses, and quartzites which ...een assigned to the Chestnut Hill series (See Report C⁵ Part I.) ...es defining the position of the worked bed, conform to the ...l direction of the strike of all the rocks within the area ...ered by this map.

...p of the Kaolin bed and immediately associated strata ...s from 45 to 58 degrees toward the south-east, perpen...ar to the strike of the bed.

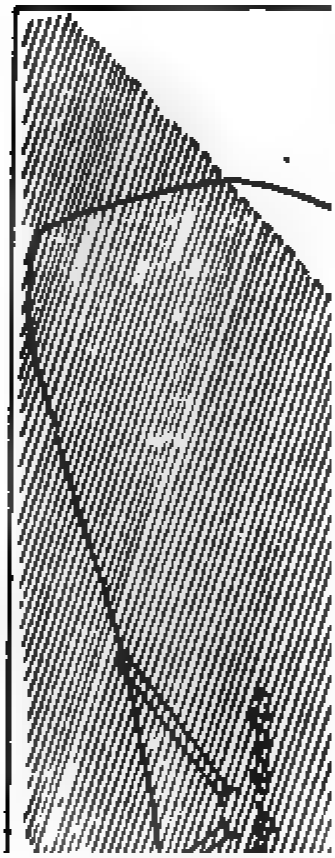
...TER

1. Soil, loam, and gravel,	23′	
2. Yellow clay (Grade No. 3, Brandywine Summit Kaolin Works,)	7′	
3. Clay; very poor; containing considerable mica, sand and refuse material,	20′	
4. Yellow clay, (Grade No. 2,)	6′	
5. Clay; very poor; similar to stratum No. 3,	4	
6. Loose siliceous feldspar, sandstone, mica-schist and hard yellow clay,	1′	8″
Total thickness,	61′	8″

From a careful examination of the above section it was judged that the bottom of the kaolin or undecomposed feldspar had been reached at the foot of the shaft, but, in order to determine this fact more conclusively, and at the same time to locate the south-east limit of the bed and to ascertain the character of the clay across the bed, several gangways were driven from the foot of the shaft in strata Nos. 4 and 5 of the above section. These gangways explored the kaolin in all directions to a distance of from 30 to 50 feet from the bottom of the shaft. These underground workings as they were abandoned during the third week of August, and the outlines of Pit No. 1, when the shaft was located, May 22d, are shown on the accompanying plate (page 596).

The fact that the bottom of the shaft was below the kaolin, and that nothing but undecomposed rock could be expected at a greater depth, was confirmed by the same rock, forming stratum No. 6 of the section, being found at a number of points in the gangways driven to the south and southwest of the shaft; the floor of the gangways being formed by undecomposed rock. In places the rock was picked through several feet, in order to ascertain its character, and it was found composed of loose siliceous feldspar, irregularly mixed with a ferruginous sandstone, and partly decomposed mica-schist containing some pieces of undecomposed feldspar and some pieces of hard yellow clay measuring a few inches through.

The southern limit of the clay-bed was passed through by the gangway driven directly from the shaft, and at a distance from the center of the shaft of 35 feet 6 inches. This



gangway was continued 4 feet further into the top wall of the clay-bed, which was found to consist of very ferruginous mica-schist partly decomposed. The conclusion, that this determined the edge of the clay-bed, was further confirmed by a gangway driven for a distance of 43 feet north-east from the end of the shaft gangway; the contact plane between the clay-bed and the mica-schist top wall was determined at a number of points along the south-eastern side of this gangway.

The bottom and the eastern limit of the bed having been thus determined from the shaft workings, the gangways were only driven further in order to ascertain some of the characteristics of the bed and the quality of the kaolin. The three gangways driven north-west, as shown by the page plate, were stopped at a north-east and south-west line, passing through the pit workings at a point north-west of which the clay-bed was completely exposed in the west end of the pit.

In order to locate the north-west limit of the clay-bed a monkey drift was driven from a desirable point in the pit north-west, as indicated on the page plate. The tidal elevation of the bottom of this drift was 242 feet, or 31 feet below the top and 41 feet above the bottom of the shaft. This monkey drift was driven in clay similar to stratum No. 2 of the shaft section for a distance of 25 feet from the mouth of the drift. Kaolin and then undecomposed rock material was encountered much similar to that found on the north-west side of the clay-bed at the four pits already referred to—three on the Griffin farm and one on the Johns farm.

The strike of the clay-bed between the shaft workings and the north-eastern end of Pit No. 1 was readily ascertained from these facts to be north 46 degrees east, and the horizontal width of the bed at right angles to the strike line 104 feet or on an average of about 100 feet. Another monkey drift was driven from the pit north 47 degrees east for a distance of 50 feet, starting at the same level as the first monkey drift referred to, and 8 feet south-east of the mouth of the latter drift. A careful examination was made in this drift of the characteristics and quality of the kaolin

passed through and also of the kaolin obtained in the pit between the monkey drift and the shaft.

The examination of the clay-bed in Pit No. 1, in the shaft workings, and in the two monkey drifts, together with measurements and estimates made from point to point of the relative proportions of white clay, of yellow clay, of the refuse material composed of sand, mica and worthless clay, has permitted of careful estimates being made as to the amount and proportion of milling clay which could be removed from the bed in the vicinity of Pit No. 1 to the total amount of material necessary to be removed in open cut work, and to the total contents of the clay-bed itself. These estimates are given later.

Although the decomposition of the original feldspar bed, from which the kaolin has been derived, varies along well defined but irregular lines, and although the constitution of the decomposed mass is more kaolin* at one point, more sand at another, and more mica at a third point; (the kaolin being of varying color, from cream to dark ocher yellow) yet at several points in the shaft workings and in the pit, where the fresh surface of the clay was exposed, there were clearly marked lines of stratification, with a dip varying from about 45 to 50 degrees toward the south-east. This same dip was observed in the material forming the top wall of the clay-bed, in the underground workings, south-east of the shaft. At several points on the Johns farm a similar south-east dip was observed.

The general strike of the mica-schists, slates, quartzites and sandstones in the vicinity of the valley in which the kaolin pits have been sunk is, in a general way, the same as a line connecting the three pits on the Griffin farm with the large pit on the Johns farm, so that there remains no doubt but that the Brandywine Summit kaolin bed was directly decomposed from a feldspar bed *in situ*, the feldspar being interstratified with the mica schists, slates, and sandstones, which have been referred to as the Chestnut

*The amount of kaolin obtained at any one point depends primarily upon the extent and character of the original feldspar contained in special portions of the bed before decomposition took place.

Hill series in the published field notes (Report C[5]) on Delaware county. The amount of kaolin which has been found at different points on these farms and its distribution through the mass of the clay-bed will be referred to later.

As has already been suggested by Professor Lesley, I believe that the drainage water, which found its way along the cleavage planes and planes of stratification through the feldspar bed, has been largely the cause of the decomposition of the feldspar into kaolin. As will be observed from the accompanying topographical map, the exploring shaft at Pit No. 1 is on a divide between the head waters of Beaver creek and Harvey's run, and if drainage water has been an active agent in the decomposition, it would be natural to infer that the original feldspar bed is decomposed to a greater depth, both north-east and south-west of Pit No. 1, than at the shaft in the vicinity of this pit.

In the western part of the National Kaolin pit a shaft has been sunk through white kaolin to a depth of 75 feet, the top of the shaft being about 30 feet below the original surface of the ground before the pit was dug. The shaft was not sunk deeper on account of its encountering a very siliceous clay, which was not as completely decomposed and which did not contain as good kaolin as that found in the bed at higher levels. It may be inferred, however, that the bottom of the clay-bed or the decomposed feldspar, similar to that found at the foot of the shaft in the vicinity of Pit No. 1, on the Griffin farm, is probably at least 10 or 15 feet below the bottom of the National Kaolin Pit shaft.

From explorations which have been made in the National pit, Mr. Johns believes that no clay of sufficient commercial purity, which would be profitable to work, would be found below the level of the bottom of this shaft. The tidal elevation of the top of the National Pit shaft is 170 feet, and the distance between Pit No. 1 shaft and the National shaft is 2645 feet, in a direction south 45 degrees 45 minutes west. The elevation of the bottom of the National shaft is 95 feet above tide, and of Pit No. 1 shaft 201 feet above tide, so that the decomposed feldspar is 106 feet lower at the former shaft than at the latter, the bottom of the bed

inclining toward the south-west at an average of about 4 feet in every hundred feet. Based on these facts, the bottom of the clay-bed along a line separating the Griffin farm from the Johns farm would be about 96 feet below the surface of the ground as against 62 feet below the surface at Pit No. 1, and 75 feet below the bottom of the National pit.

This plane of decomposition unquestionably inclines regularly, as suggested by Professor Lesley, from the Griffin Pit No. 1 shaft, down Beaver creek to where it empties into Brandywine creek, at Smith's Bridge. The plane of decomposition also probably slopes in the direction of the drainage into Harvey's run; possibly not at so great a rate, however, as it slopes down Beaver creek.

The dip, the strike, the width, and the depth of the Brandywine Summit clay-bed having been determined, it remains to define its geological position in the rock series.

At the eastern end of the National pit, a ditch has been constructed in order to carry off the water from the eastern end of the pit around its southern edge and into Beaver creek. This ditch has been quarried through limestone strata.

During the first week in August, 1885, after a heavy rain, the limestone and associated strata were laid bare, and I was permitted to measure a detail section. The dip of the limestone is 50 degrees, south 15 degrees east. The strata are evidently slightly contorted at this point, since the strike of the limestone, which is north 75 degrees east, was not parallel to the general strike of the clay-bed, which is north 40 degrees east. The Johns farm section is as follows:

Description.	*Thickness.*
1. Ferruginous mica-schists and sandstone, containing thin layers of brown hematite, $\frac{1}{16}$ to 1 inch thick, and seams of yellow quartzite. (These are assigned to the Chestnut Hill series in Report C^5,)	unknown.
2. Feldspar, partially decomposed into kaolin, alternating with layers of sandstone and possibly limestone. This interval is only partially exposed, and the individual strata which compose it could not be differentiated, ...	35′ 0″
3. Very ferruginous sandstone; contains thin seams of feldspar and limestone, the latter being from $\frac{1}{4}$ to 2 inches thick, ...	4′ 0″

Description. (Section continued.)	*Thickness.*
4. Crystalline limestone, ...	1′ 9″
5. Ferruginous siliceous feldspar, decomposing into loose sand and kaolin, the former in excess, ...	2′ 6″
6. Crystalline limestone, ...	0′ 3″
7. Siliceous and feldspathic limestone, decomposing into calcareous and siliceous sand, ...	0′ 6″
8. Crystalline limestone, ...	1′ 6″
9. Feldspar, ...	2′ 0″
10. Highly crystalline limestone, ...	5′ 0″
11. Ferruginous, siliceous, and micaceous feldspar, . . .	8′ 0″
12. Crystalline limestone, ...	0′ 6″
13. Feldspathic sandstone; decomposes into sand, ...	0′ 8″
e limestone, ...	0′ 7″
containing masses of quartzite, ...	6′ 0″
sandstone, containing seams of brown hem-ng the cleavage planes and planes of stratifi-	4′ 0″
feldspar; decomposes into white kaolin, .	40′ 0″
ts and quartzite, partially decomposed and forming the floor of the original feldspar bed,	unknown.
thickness, ...	112′ 3″

hich Mr. Johns has worked on the south side
est the mill, has resulted undoubtedly from
tion of the feldspar bed stratum, No. 2, in
on. At the eastern end of the pit, the kao-
rom the decomposition of feldspars Nos. 2
ively, has been opened and worked on either
posed rocks forming strata Nos. 3 to 16, in-
above section.

side of the National pit a limestone stratum
ave been cut in a water-ditch. I did not,
he exposure of this limestone. On Beaver
00 feet west of Johns' clay-mill, a little ex-
stone was found.

a represented by the section have certainly
ed in the bottom of the National Kaolin pit,
have ever been found in this pit *in situ*, com-
aving been dug from all parts of the bed for
25 feet at right angles to the strike of the
ntegration of the limestones in the above
er, suggests the conclusion that lime-water
gent in hastening the decomposition of the

original feldspar into kaolin, as has already been proposed by Professor Lesley. The exceptional whiteness of the National kaolin, and its excessive toughness, render it probably the best marketable kaolin mined in the United States. These characteristics may be determined by the lime-water coming from the limestones and filtering through the original feldspar aiding the decomposition.

The above section, together with the geological facts previously presented, furnish conclusive evidence that the Brandywine Summit kaolins have resulted from the decomposition of feldspar beds interstratified with the mica-schists, slates, and quartzites which may be found outcropping in a number of localities on either side of the Beaver and Harvey run kaolin belt.

On the Griffin farm no limestone-beds have been discovered, nor have any of the strata directly associated with the kaolin bed on the Johns farm been exposed. This, together with the fact that the kaolin of the Griffin farm is more heavily charged with oxide of iron, rendering the clay more yellow than the National clay, and that the Griffin clay-bed does not seem to be as wide or contain as great a proportion of commercial kaolin within a given area as on the Johns farm, has led to the suggestion frequently made that the deposits on these two farms are essentially different and are not directly connected. Such a conclusion, however, cannot be sustained. The essential differences in the clay on the two farms are readily explained, not only by variations which must have existed in the process of decomposition of the original feldspar bed, but also by variations inherent in the original formation and constitution of the feldspar itself.

Undecomposed feldspar beds which are found with geological associations similar to those of the Brandywine kaolin bed, are found to vary considerably in thickness, in their mineralogical characteristics, and in the foreign ingredients which they contain.

Sufficient explorations have not been made on the Griffin farm to determine the exact geological horizon of the clay-bed in the vicinity of Pits Nos. 1, 2, and 3. The clay-bed

worked in these pits, however, seems to occupy the same geological horizon as that in which the limestones, feldspars, and kaolins occur in the eastern end of the National Kaolin pit. No extensive search was made for an outcrop of these limestone-beds on the Griffin farm. Even if the explorations had been complete in themselves the limestones might not have been found, since it is quite possible for them to be decomposed on the Griffin farm the same as they are on the Johns farm, except at the isolated points already referred to. It would appear, however, from the location of these limestone outcrops on the Johns farm that the kaolin on the Griffin farm may be represented by stratas Nos. 2 and 17 of the Johns farm section; the former stratum (No. 2) when projected to the south-west from the eastern end of the National pit may lie to the south of Beaver creek, to the south-west of the present National pit. Although this may be so, it would be unsafe to conclude that a workable bed of kaolin can be found south of the creek at this place.

From the facts at present at our command the most probable location of good kaolin is within the limits of the belt defined on the topographical map.

It is not improbable that feldspar beds may be interstratified with the mica-schists, slates, and quartzites forming the hills on either side of the defined kaolin-bed, and that these feldspars may be decomposed into kaolin. Considerable exploration has been made for kaolin within the area covered by the topographical map, and outside of the defined limits of the kaolin-bed, but in every case no well defined workable bed of kaolin has been found. The topography and relationships of the kaolin-bed, at points where the Brandywine working pits have been opened, throw grave doubts upon the possibility of there being found beds of kaolin parallel to the beds now being worked, or within the limits of either the Griffin or Johns farms, outside of the boundaries defined on the map.

The amount of clay which still remains in the bed now being worked on these two farms is very great. After the completion of the explorations on the Griffin farm in Sep-

tember, 1885, an estimate was made of the amount of kaolin which still remained, similar to that which has already been worked on the Griffin farm.

After the soil on the top of the clay is removed, it is believed that but one-half of the material contained in the clay-bed can be profitably milled, and produce kaolin to be used for purposes similar to those for which the washed kaolin, which has so far been taken from the Griffin farm, has been employed. Of the clay carried to the mill but one third, on an average, is obtained from the presses as commercial clay, the other two thirds of the material being refuse, principally composed of white sand. In other words, on an average not more than one sixth of the contents of the clay-bed can be considered commercial kaolin. It may not be even safe to estimate actual values on this basis, so that, in the following estimates, I have made a reduction of 10 per cent. This would certainly bring the estimates within reasonable limits of safety.

The thickness of the soil overlying the bed varies from 12 to 25 feet. The soil necessary to be removed from the top of the bed before mining can be carried on by open work, consists of a prismoid on top of the kaolin bed, and a wedge on either side sufficiently large to prevent the soil from falling into the excavation made by the removal of the clay. The tendency of both the kaolin and soil above it to slip is so great, particularly in the vicinity of the springs which are frequently met with along the bed, that it is impossible to make any exact estimate of the amount of soil which must be removed, in order to permit of all of the good clay being obtained by open work. If the average depth of soil be assumed as 20 feet, and the average width of the kaolin-bed be taken as 100 feet, there will have to be removed 2600 cubic feet, or 117 tons, (2000 pounds) of soil for every running foot along the bed. That is, on the Griffin farm there will have to be removed an aggregate of $\frac{1}{4}$ of a million tons of soil in order to lay bare the surface of the kaolin bed.

The elevation of the ground at the edge of the National pit, near Mr. Johns' office, is 37 feet above the top of the

Johns shaft already referred to, so that the depth to which the kaolin has been tested in the Johns pit is 112 feet below the surface of the ground. The horizontal width of the kaolin-bed in this pit is about 125 feet. The average depth, below the surface of the ground, of the bottom of the kaolin bed on the Griffin farm, south-west of pit No. 1, is 80 feet, and the average depth, below the surface of the ground, of the bottom of the bed on the same farm, north-east of pit No. 1, is 65 feet. Allowing 20 feet for the average thickness of the soil, the average thickness of the kaolin-bed in one case would be 60 feet and in the other case 48 feet. Assuming an average width for the pit as 100 feet, the bed would contain 746,250 tons of material, of which 373,125 tons might be considered minable clay. Allowing 10 per cent. reduction for safety, this would make the Griffin farm contain 112,000 tons of commercial kaolin, or about 40 tons for every running foot of the bed. The length of the bed on the Griffin farm is 2850 feet.

The quality of the clay, which we can reasonably expect to obtain in the future, cannot vary considerably from the quality of the clay which has been produced from the bed up to this time. The bulk (at a minimum estimate 90 per cent.) of the kaolin which the Griffin farm will ever produce will undoubtedly be yellow. This grade is locally known to the trade as grade No. 2, grade No. 1 being that produced by the Johns farm.

No estimate has been made of the amount of kaolin which may be obtained from the Johns farm, but when it is considered that the bed here is wider and deeper than elsewhere, and the proportion of milling clay to refuse material is greater than at other localities, it may be safely assumed that more than twice the amount of kaolin for every running foot along the bed is contained on the Johns farm than is contained in the bed on the Griffin farm. At the same time, it is safe to assume that the quality of the kaolin which can be obtained from the Johns farm in the future will be quite equal to the grade that has already been mined. In fact, from a consideration of the geology of this deposit, and the relationship and position of the bed

to the topography of the surface, it is more than probable that the kaolin which can be worked from the Johns farm, south-west of the present pit, will be greater for every running foot along the clay-bed than the amount so far obtained, and that the kaolin may more reasonably be expected to be of a superior rather than of an inferior quality to the white kaolin which the Johns farm has shipped to market in the past.

No reliable statistics are to be commanded of the amount of clay which has been removed from the National kaolin pit for the past 25 years, during which time clay has been mined on the Johns farm. In a communication recently received from Mr. H. A. Johns, he reports that during the first year the production of washed clay was very small, probably not over 500 or 600 tons, 1000 tons being the maximum for any one year. This was prior to 1873, when Mr. Johns commenced operations. Since 1873 the production of the farm has increased somewhat, and there has probably been sold to the trade, since the pit was opened, about 20,000 tons of washed clay. To obtain this amount, about 60,000 tons of crude clay has been removed from the pit, and there has probably been handled 500,000 tons of material, including the crude clay and all refuse material.

What now composes the Griffin farm is made up of the Isaac Bullock farm, to the south-west, and the Hamilton Graham farm to the north-east. Although on both of these farms clay has been dug independently from pits Nos. 2 and 3, prior to 1880, when these two farms were purchased by Mr. John Griffin, yet at the above date practical mining may be said to have been commenced.

The capacity of the mill on the Griffin farm is greater than that on the Johns farm.

Clay Mining.

There have been three methods adopted for working the Brandywine Summit clay bed, as follows:

1. Open pits.
2. Small hoisting shafts and gangways.
3. Large open shafts.

1. The open pit system was first employed, and is even now used to a great extent. It is a system common to the working of all mineral deposits by open pits or quarries, and consists in first stripping from the surface of the clay-bed all the soil, gravel, and other foreign material, and then digging directly into the clay-bed. Although this system has been a profitable one and is still used, there is probably no mineral deposit where this plan of working the bed is more hazardous and expensive than in a clay-bed, such as the Brandywine Summit.

The amount of soil and gravel which has to be removed before the surface of the clay-bed is exposed varies from 10 to 20 feet. The gravel has to be sloped for a considerable distance back from the edge of the bed to prevent the over-
rial around the edge of the hole from caving in
up the pit. The original feldspar is so completely
d into clay that as soon as an excavation is made
a movement of the whole mass starts and con-
l the excavation is entirely re-filled. This move-
e clay-bed and the overlying material is of course
quickened by rain water, and by the water com-
prings beneath the surface of the ground.
e quarry this difficulty does not exist, owing to
y of the rock. In a clay-bed, however, a slight
in will start the whole mass moving, and in a few
rge surface of exposed clay may be completely
y hundreds of tons of mud and gravel, which
emoved before work in the clay can be again car-
The dead work which is required before commer-
n be gotten, by this method of mining, and the
f carrying a considerable stock of crude clay on
rmit of the continuous running of the mill and
shipments, requires a large amount of working
d makes the mining, even under the most favor-
nstances, risky.

g the past three years the system of mining by
ing shafts and gangways has been extensively
by H. A. Johns & Co. This system consists in the
a shaft, about 4 or 5 feet square, down to the bot-

tom of the clay-bed, or to any part of it from which clay is particularly desired. The shafts which have been sunk in the bottom of the National Kaolin pit have never exceeded 75 feet in depth. The shafts are heavily timbered in sinking, and from the bottom of the shaft gangways are driven in all directions into the clay. The movement of the clay is so continuous, and the pressure brought to bear upon any obstruction to the movement to the clay so continuous, that these gangways can only be kept open a few weeks.

planks in the second row, in the same way as in the first row. It is desirable to have the wedges in two successive rows of planks driven into the side of the shaft at opposite points. Sometimes it is found not to be necessary to put a wedge in each course of planks.

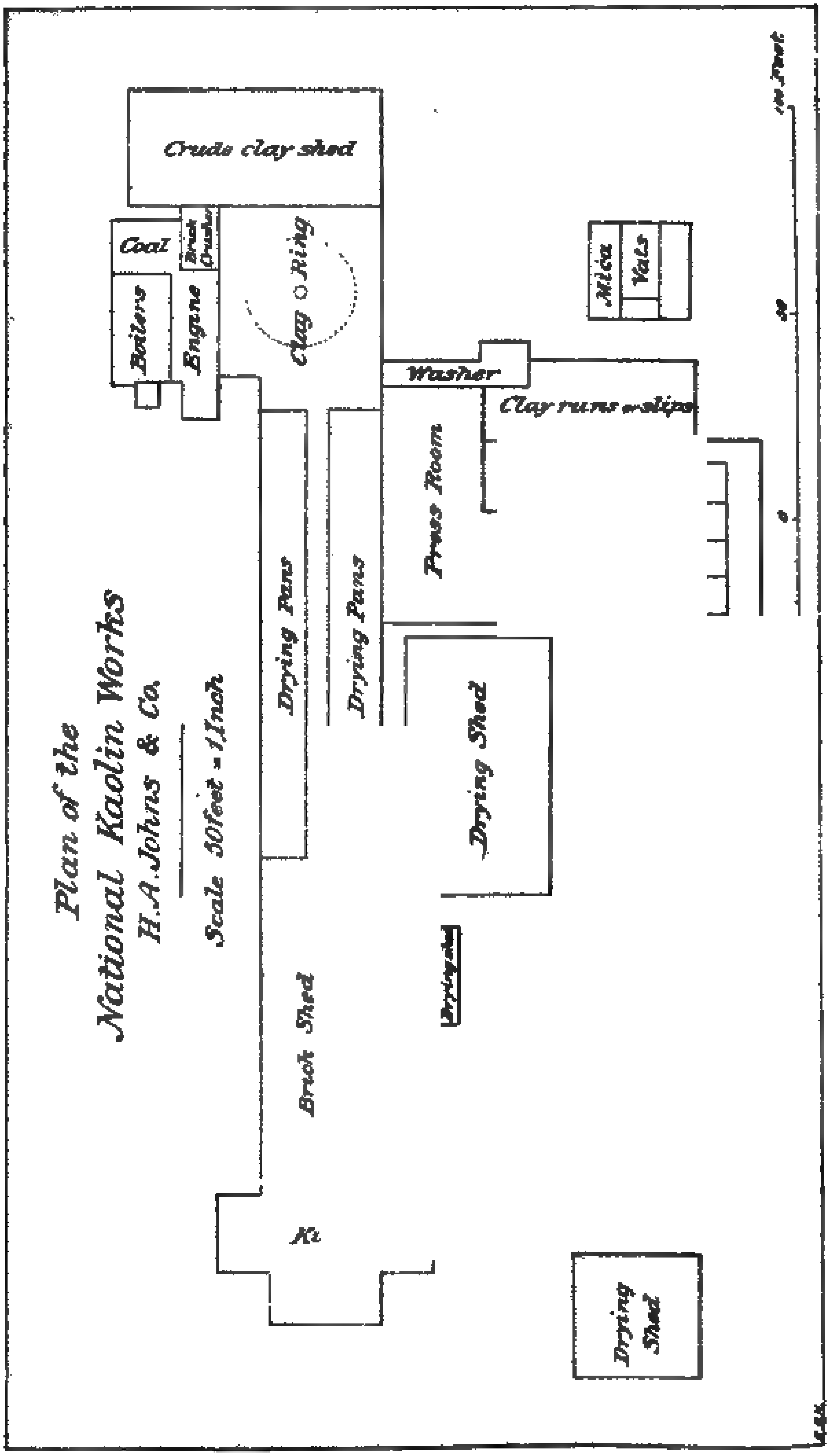
After the bottom two courses of planks are properly laid, they are spiked together by large iron nails. On the top of these bottom two courses, other planks are laid in a similar way until the lining of the shaft is continuous to its top. The shaft is then dug 4 or 5 feet deeper and below the bottom of the planks which have so far been laid. The wedges in the different courses of plank, and the spikes between the two bottom courses, make the lining of the shaft sufficiently rigid, as a whole, to prevent it from falling down when the shaft is sunk deeper beneath the bottom course of planks.

After the shaft has been sunk to a depth at which its unexposed sides are liable to cave in, planks are laid around the shaft, commencing at the then bottom of the shaft and extending up to the bottom course of planks previously laid. The shaft is thus alternately sunk and lined in sections until the bottom of the clay-bed is reached. The depth to which the shaft is sunk, between the times during which digging is stopped in order to permit of the shaft being lined, depends entirely upon the character of the clay passed through by the shaft and its ability to stand without lining.

By this method all the clay which is obtained is taken from the shaft itself. When the sinking of any one shaft is ultimately stopped, a second shaft is commenced in another part of the clay-bed, and the refuse from the second shaft is dumped into the first shaft, the hemlock planks which lined the first shaft being taken out as the shaft is filled up with refuse material.

This system of mining was originated by Mr. Golding in the clay-beds in the vicinity of Hockessin; it has recently been introduced at the National Kaolin pit by Mr. Johns.

While all of these three systems of mining have their individual advantages, under special conditions, it is believed from the experience in the Hockessin clay-beds, that


Plan of the
National Kaolin Works
H. A. Johns & Co.
Scale 30 feet = 1 inch
Crude clay shed
Coal
Brick Crusher
Boilers
Engine
Clay Ring
Washer
Clay runs & slips
Mica
Vats
Press Room
Drying Pans
Drying Pans
Drying Shed
Drying shed
Brick Shed
Drying Shed
100 Feet

the third system will as a rule prove most generally profitable.

Preparation of clay for market.

The clay, as taken from the pit, is not fit for the potters' use, and it is necessary to separate the pure clay from all deleterious ingredients. To accomplish this end, the crude clay, before it is hauled from the pit to the mill, is separated by careful digging and handling from a large mass of sand with which it may be associated. It is then hauled to the mill and placed on the stock pile, from whence it is taken and dumped into the mixing trough, in which the clay is thoroughly broken up and mixed with water.

The clay and sand mixed with water runs into a trough in which a vertical wheel revolves, with pocket elevators on its circumference. The sand in this trough settles to the bottom, and is carried off by the pocket elevators.

The water, holding the clay in suspension, then passes into board troughs known as "clay-runs" or "slips." These slips are placed side by side, and the clay in going through them is carried over a distance of between 600 and 900 feet. As the clay passes through these troughs the sand falls to the bottom and is ultimately removed from the troughs.

The water holding the clay in suspension passes from the last run into settling vats, where it is permitted to remain for several hours or several days. As the pure clay sinks to the bottom of the vat the clear water is drawn off from the top.

From these vats the clay is then pumped, under pressure of about 160 pounds, into canvas cloths folded with their edges turned over and placed in hydraulic presses. These presses contain from 34 to 40 such canvas bags included between tightly connected frames. By continual pumping it takes from 6 to 14 hours to fill these presses, the length of time being dependent upon the toughness and tenacity of the kaolin. The National kaolin is extremely tough, and requires a longer time, under the same conditions for pump-

ing into the presses, than the clay mined on the Griffin farm or in the Hockessin district.

After the presses are filled with kaolin the connection with the pump is broken, and the leaves of the presses are opened, and the canvas cloths unfolded and emptied of the clay, which is then placed on shelves in the open air for drying. The time which is required for the clay to dry depends upon variable conditions.

The accompanying plates on pages 610 and 612, show the plan of the clay mills on both the Johns and Griffin farms.

The general system of preparing the clay by both of these works is practically the same, the details of the method being slightly varied by local features which characterize each mill.

In addition to the plant necessary for the preparation of clay in the Johns mill, there is placed in the rear of the mill a brick shed, two drying pans and a clay ring, these special parts of the mill having been designed for the manufacture of fire-bricks.

The most prominent difference at the Griffin mill consists in the necessary machinery required for pulverizing quartz rock and feldspar, both of which are sold to potters for

The quartz and feldspar are ground up
hich consist of large porcelain-lined cylin-
made to revolve more or less rapidly by
In the cylinders, with the rock to be
d a variety of hard quartz pebbles, known
es, which, being mixed up with the rock,
mpalpable powder. Before the quartz or
l in the Alsing mills it is ground up into
heavy mill-stone revolving around a hori-
h, in turn, revolves around a vertical shaft.
in, known to the trade as No. 1, which is
A. Johns & Co., commands a high price,
the potteries principally at Trenton, New
a specialty of making the highest grades
a.

r, which is slightly discolored by oxide of
considered not to be as tough as the white

ANNUAL REPORT 1885. GEOL. SURVEY, PA.

HELIOTYPE PRINTING CO., BOSTON, MASS.

ARCHBALD POT-HOLE NO 1:

EATON COLLIERY, JONES, SIMPSON & CO.,

LOOKING INTO HOLE FROM ABOVE.

Notes on the Quaternary Geology of the Wyoming-Lackawanna Valley in Luzerne and Lackawanna counties.

I. Description of the Archbald Pot-holes; also of the Buried Valley of Newport creek near Nanticoke with special reference to the "Nanticoke Mine Disaster," of December, 1885, by Charles A. Ashburner.

II. Description of the Buried Wyoming Valley between Pittston and Kingston, by Frank A. Hill.

III. Description of a new substance resembling Dopplerite, from a Post-glacial Peat Bog at Scranton, by Henry Carvill Lewis.

I.

Introduction.

During the glacial epoch of the Quaternary period of the geological column, or, as it is popularly referred to, "the Cold Age," all of Canada, New England, New York, Northern New Jersey, and Pennsylvania, down to a line starting from Olean, in Western New York; extending through Ralston, in Lycoming county; Berwick, on the north branch of the Susquehanna river; White Haven, on the Lehigh river, and Belvidere, on the Delaware river, was covered by a continuous and solid sheet of ice. This ice sheet was variable in thickness. In New Hampshire it was probably 6000 feet thick, while in the Wyoming-Lackawanna Valley Prof. Lesley expresses his opinion that it was at least 2000 feet thick.

This ice sheet moved slowly forward toward the south and south-west, ploughing and scratching the surface of

the country, and carrying with it rocks of all kinds and sizes, from fine grains of sand to huge blocks several feet in thickness. This drift material was dumped by the glacier along its edges in the form of moraines, or dropped from the bottom of the glacier as it passed over the hills and valleys. Evidence of this is not wanting on the ground within the area referred to.*

Fragments of outcropping rocks from an older geological age were broken off and were carried by the glacier over hills and across valleys, and dropped upon the outcrops of rocks of a later geological age. Valleys originally deep have been filled up by the glacial drift, and the beds of streams have thereby been elevated; the streams flowing now at higher levels than prior to the glacial epoch.

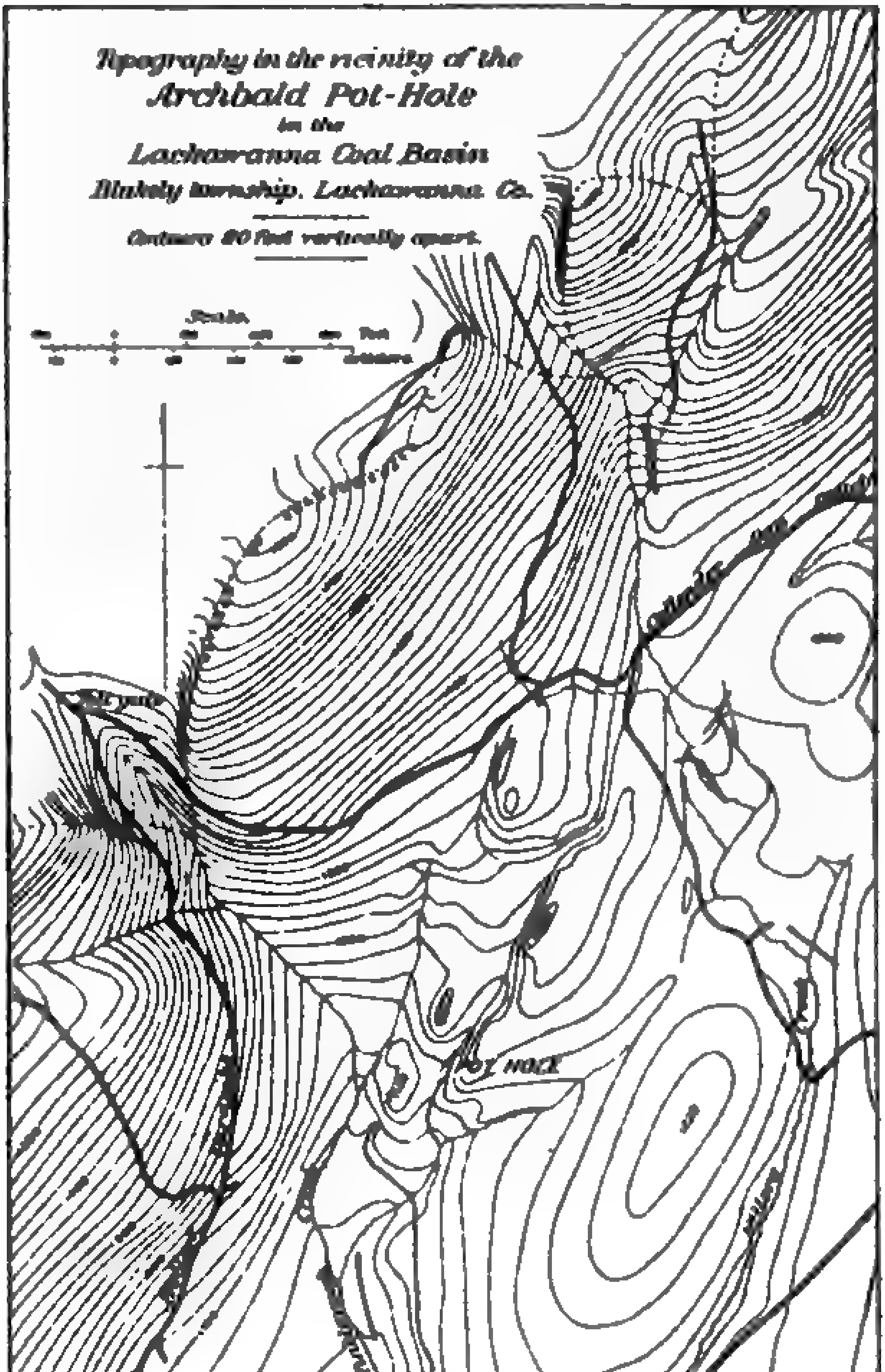
A glacier covered, at one time, the entire Wyoming-Lackawanna valley, and extended as far south as the lower part of Luzerne county, where its terminal moraine runs through Foster, Butler, and Nescopec townships. North of this line glacial drift exists on the tops of hills and fills the bottoms of valleys.

In the lower part of the Wyoming-Lackawanna valley we find the presence of drift universal, the depth of the drift being determined by the difference in elevation between the bottom of the original valley, as it existed before the glacial epoch, and the elevation of the bottom of the valley as it is to-day.

The depth of this drift and the location of pot-holes in areas underlaid by workable coal-beds, is a matter of great practical importance to coal operators. The depth and character of the drift have a direct practical bearing upon the sinking of shafts, from which to work the coal-beds. The thickness of the rock roof over the mine workings between the top of the workable coal-beds and the bottom of the drift, is no less important as affecting the possibilities and safety of mining enterprises.

The location of points where the outcrops of worked coal-beds will be covered by a considerable depth of drift, and

*See Report Z.


Topography in the vicinity of the
Archbald Pot-Hole
in the
Lackawanna Coal Basin
Blakely township, Lackawanna Co.
Scale.
POT HOLE

chamber from the air-way, when they encountered a mass of round stones weighing from one to six or more pounds, which were resting like a wall in front of them and which extended across the face of the workings, from within about one foot of the bottom of the "*vein*," up to the roof; worked around it and found the coal regular, with this pillar standing in an almost oval shape, (greatest length about 20 feet); started to clean it out and found it ran through the rock to the surface, a distance of over 40 feet."

This hole is situated on one of the head branches of Tinklepaugh creek, nearly three miles (15,200 feet) north 50° 45′ west of the Delaware and Hudson Canal Company's railroad station at Archbald. The accompanying page plate topographical map shows the position of Pot-hole No. 1, the most prominent topographical feature in the vicinity being the Callender gap, through which the Brown Hollow turnpike passes, north-west of the hole.

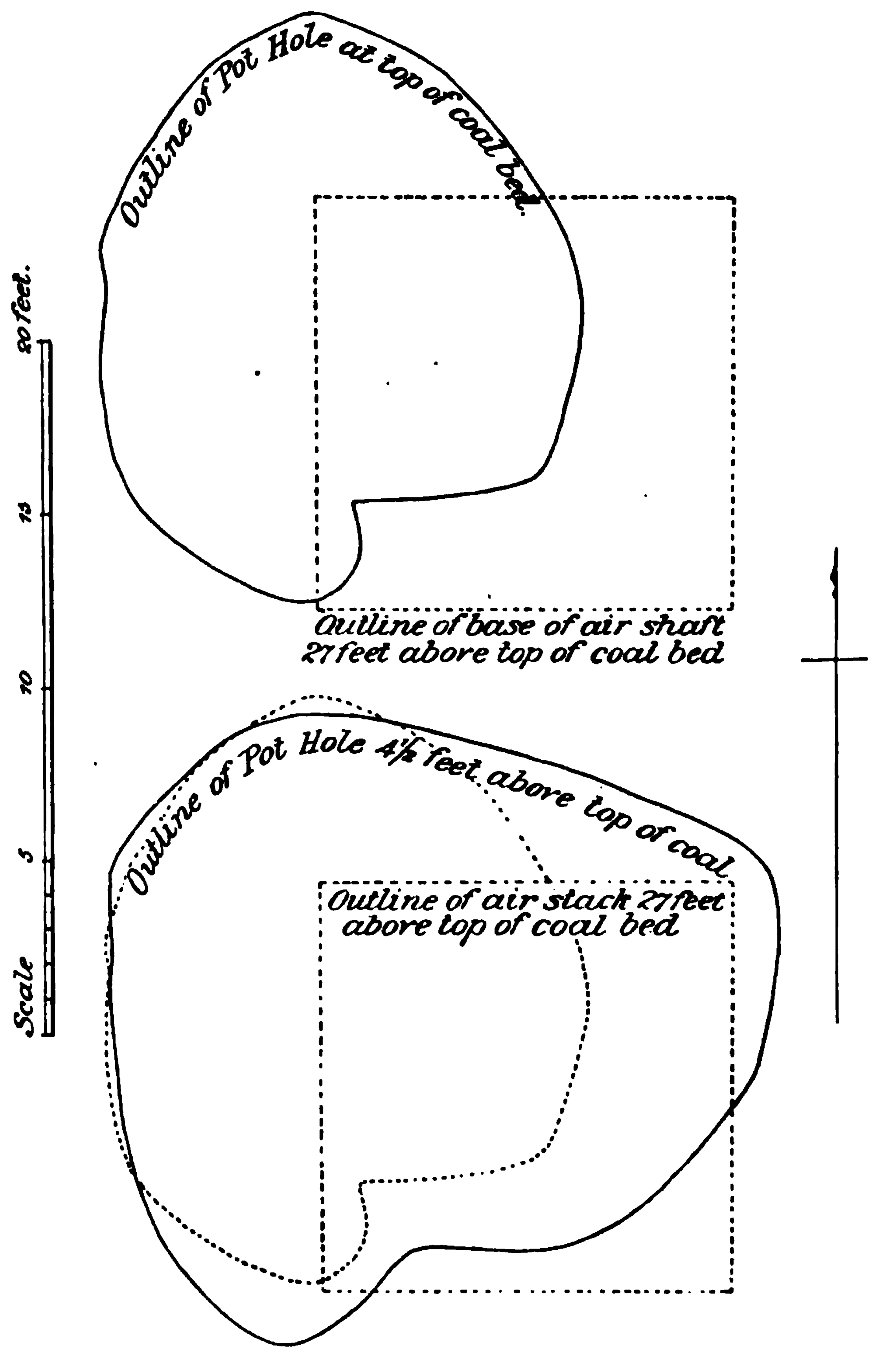
In May, 1885, the second or upper pot-hole was discovered by the miners of Jones, Simpson & Co. in the same way that the first hole was discovered. The position of this pot-hole is not shown on the page plate map. It lies in the same hollow as Pot-Hole No. 1, and 1000 feet north 33° east of it. Pot-Hole No. 1 is at present used for an air-shaft in ventilating the Ridge mines.

The elevation of the top of Hole No. 1 is 1129.48 feet above tide, the elevation of the railroad track at Archbald being 916 feet A. T. The depth of the hole is 38 feet. The greatest length of the hole on the surface of the ground is 42 feet in a direction of north 80° east, and the shortest width across the top of the hole is 24 feet.

The general position of the hole is not vertical, but inclined in a direction south 80° west. The hole extends to the bottom of the Archbald coal-bed, which, in the mines in the vicinity of the hole, is eight feet thick.

The accompanying plate (page 620) shows two carefully measured sections of the hole, one immediately on top of the coal-bed and one 4½ feet above the top of the bed, these sections being referred to the position of the base of the air stack, 27 feet above the top of the coal-bed.

Sections of the Archbald Pot-Hole.



Greatest distance across top of hole 42 feet.
Shortest distance across top of hole 24 feet.
Depth of the hole 38 feet.
Bottom of the hole is on the floor of the Archbald coal bed which is 8 feet thick.

The hole on top of the bed is 14 feet wide, east and west, and 17 feet long, north and south; while 4½ feet above the top of the bed it is 19 feet east, and west, and 18 feet at the widest point, north and south. Between these two sections the west face of the hole is nearly vertical, while the east face inclines toward the east.

The accompanying heliotypes (opposite pages 615 and 617 respectively) show two photographic views* of the hole, one taken from the top looking down, and the other taken from the bottom looking up. The bottom of the first view is along a line run nearly north and south, north being to the right-hand side of the heliotype; the sides of the second view point upward toward the north.

The hole is cut almost exclusively out of slate and sandy shale, principally the former, and the faces of the hole are extremely smooth. The pebbles taken out of the hole were from sedimentary strata, and, as far as could be determined, from strata geologically above the Pocono sandstone, No. X, which forms the highest summits north and north-east of the hole.

A number of the pebbles taken from the hole were evidently formed from the rock which was cut out of the hole, and among them there were several pebbles cut from the coal-bed itself. One of these latter pebbles, which I saw, measured about 5 inches in diameter.

I did not visit this hole, but the facts connected with its discovery were reported to me by Mr. John C. Branner, topographer in charge of the topographical survey of the Lackawanna valley, as follows:

"It was found working a drift in very similar to that which found the first hole, and fell into the mine workings when they advanced in the vicinity of the hole. To prevent inconvenience in the mine workings, if the sand and drift should come into the hole, the material was propped up and confined in the hole and thereby kept out of the mine breasts."

Since this hole was not cleared of its contents when vis-

* The heliotypes were printed from excellent negatives made by Mr. Frey, of Scranton, who placed the negatives at the disposal of the Survey.

ited, it is impossible to describe its form in detail, but from information furnished by Mr. Edward Jones, of Jones, Simpson & Co., its position and depth were readily ascertained, the former from the company's mine map, and the latter from Branner's instrumental elevations.

The depth of hole No. 2 is 50 feet, as follows:

Elevation of rail at the mouth of the mine drift,	1077.95′
Elevation of top of pot-hole, (topographical station 8872,)	1192 07′
Elevation of floor of mine at bottom of hole, ...	1027.45′
Height from bottom of hole to surface, ...	64.62′

From observations made upon the depth of the soil and gravel overlying the surface of the rocks, in the vicinity of the hole, it is probable that there is between 14 and 15 feet immediately over the hole, say 14.62 feet, thus making the depth of the hole, according to Mr. Branner, about 50 feet.

I am not informed as to the diameter and shape of this hole. Its dimensions are locally spoken of, however, as being less than the dimensions of Hole No. 1. Its depth, is certainly greater, and it is more than probable that its diameter is also greater than the diameter of Hole No. 1.

Before referring to the probable manner in which these holes were formed, a reference to the prominent topographical features of the area surrounding the holes is necessary. These are shown on the page plate map (page 618). Mr. Branner, in referring to the topography, says:

"The little hollow in which both the holes are located is ½ mile long, and in this distance rises about 95 feet, in a direction of north 32° east. At the lower end of this little valley the hill tops on either side are about 500 feet apart, and in elevation about 70 feet above the top of the first hole, which is at the lower end of the valley. A 'wet weather' stream runs down this hollow during the greater part of the year."

If the branch of Tinklepaugh creek, which now flows through Callender gap, north-east of the holes, at some anterior period was united with the branch of the same creek, now occupying the hollow in which the pot-holes are located, the area drained by both streams would be less than 2 square miles.

If these two branches of Tinklepaugh creek never united in the vicinity of the holes, the area drained by the stream now occupying the hollow in which the holes are located would be about a quarter of a square mile It has been suggested that at one time Miller's creek occupied the hollow through which Tinklepaugh creek now runs. This, however, is highly improbable, but even if it was the case, the area drained, through the hollow, would only be a little over two square miles.

Under any of the above hypotheses, the amount of water which at any one time could have flowed over the holes would have been comparatively small. Mr. Branner has determined, from his surveys, that the Lackawanna river at Archbald drains an area of 104 square miles, and he has estimated that, at the average height, this stream discharges at this point less than 100 cubic feet of water per second.

These facts are presented here as bearing upon the possibility of these pot-holes having been formed during recent times, by the fall of water, resulting from natural drainage, in the same way that pot-holes are now being formed in the beds of our mountain streams.

When, the maximum amount of water which could possibly be obtained during recent times to flow through the hollow in which the holes are located, the depth of the holes, their diameter and size, and the character of the pebbles contained in the "gravel filling" of the holes, are all considered, it would appear not only improbable but absolutely impossible that the holes should have been formed in the manner suggested.*

Immediately after the discovery of Pot-Hole No. 1, and before any careful examination had been made of the hole

---

*Shortly after my visit to Pot-Hole No. 1, May, 1884, as the result of a conversation had with Mr. Branner, he obtained the idea that I suggested the theory that these pot-holes were formed by water falling down into the hollow in which they were situated, at a time when the stream was larger than it is at present, or by a stream coming from the direction of Callender gap.

I certainly failed to make my views clear to Mr. Branner, since I never entertained such a theory. Reference is made to this fact here, since in a paper recently read by Mr. Branner before the American Philosophical Society, on the Glacial Geology of the Wyoming-Lackawanna Valley, he credits me with having entertained such a theory.

or its surroundings, Professor Lesley, in a letter to Jones, Simpson & Co., suggested that this hole was formed by water falling through a crevasse in the glacier, which, during the glacial period, covered the Lackawanna valley to a depth probably of 2000 feet, by the same process that potholes are now being made every day, under the Alpian glaciers. Illustrations of similar holes are preserved in the public garden of the city of Lucerne, Switzerland, where five or six such holes are kept open for the amusement and instruction of the public. When they were cleaned out a number of rounded stones, some of large size, were left in them, so that the people could see how the holes had been made.

Although this explanation was only suggested by Prof. Lesley without any facts other than the depth of the hole as reported to him, and was never intended to be a final statement, reference is made to it here, because Mr. Branner, in his paper read before the American Philosophical Society, says:

"After having gone over the ground repeatedly, and after having made a thorough study of the topography of this region and all that appeared to be questions that would throw any light upon the subject, the more firmly am I convinced that this explanation *suggested* (by Prof. Lesley) is the true and the only possible explanation."

That the cause of the pot-hole must be sought for during the glacial period there can be no question, because only during that period can we conceive of sufficient water resulting from the melting of the existing ice sheet, to produce such a phenomenon.

The hole could not be formed except by water in sufficient quantity, and having sufficient velocity to keep the sand and pebbles in constant ebullition, when entering a depression in the surface, otherwise any depression in the bed of a stream of small size would be quickly filled by the mud, sand and pebbles and such a stream would flow over the filled hole, rather than into an empty one.

If, however, a great volume of water should impinge on the surface of the rocks, where the hole is now found, with

considerable force, the rocks at the point of the water-fall would be worn away, not only by the direct force of the water, but by the fall of the sand and pebbles carried by the water, and by the constantly movings and and pebbles caught in the hole, but too heavy to be kept in such violent action as to flow out with the water. This is the method by which pot-holes are formed at the bottom of glacial crevasses. All water falls through glacial crevasses are themselves approximately vertical. Especially would such water-falls be vertical where they fell from a height of several hundred feet.*

Pot-holes formed by a crevasse water-falls would be nearly symmetrical about an approximately vertical line, very unlike in this respect Pot-Hole No. 1, the shape of which indicates that the force of the stream which impinged upon the rocks during its formation must have inclined in the direction of the axis of the hole.†

In only two ways is it possible for me to conceive of this hole being formed:

First. By the water which always flows underneath a glacier, particularly near its terminus.

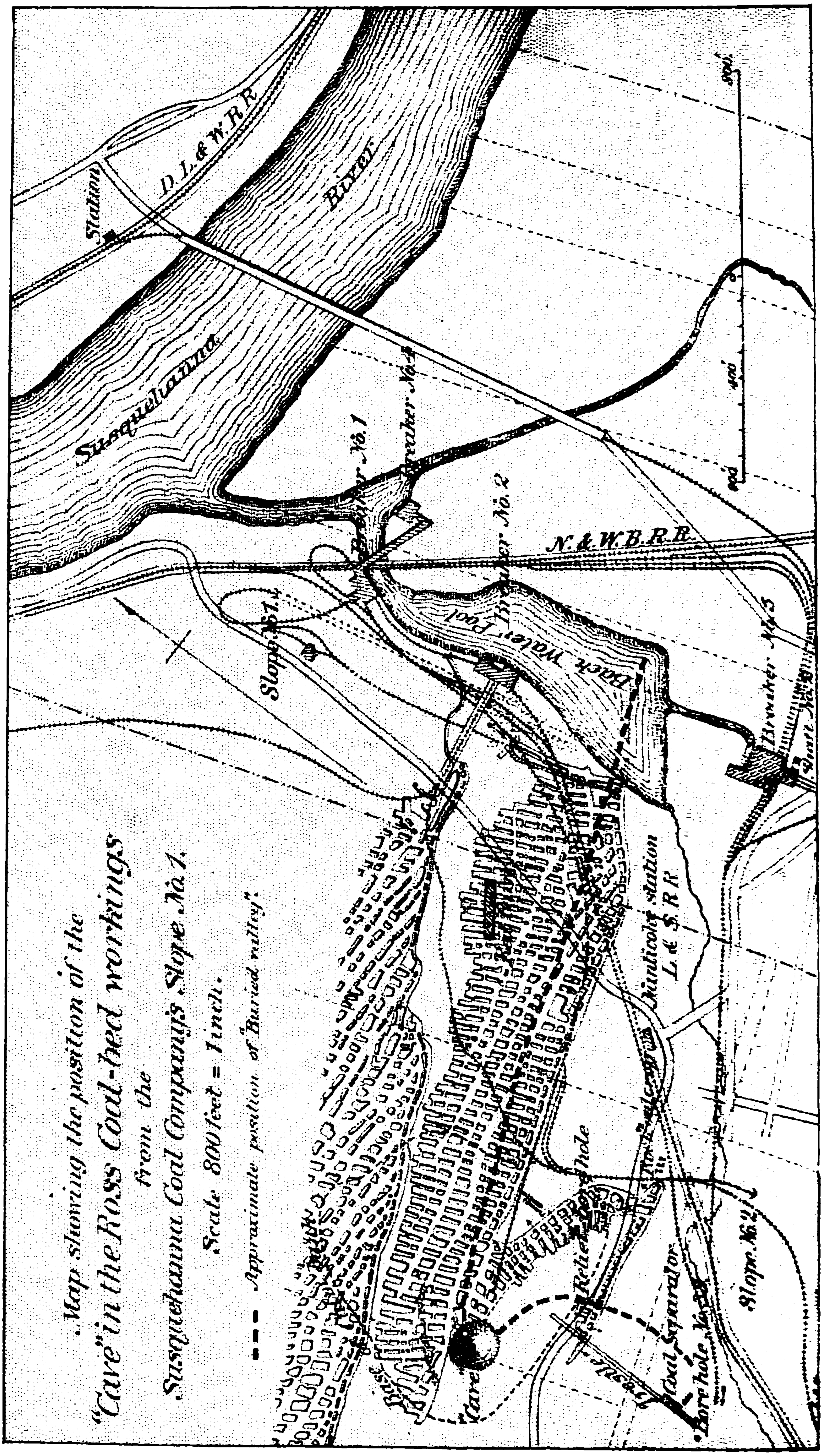
Second. By water flowing over the edge of the retreating ice, at the terminus of a glacier.

In either case we would have sufficient water to form the hole, and the inclined directions of the water as it fell upon the rocks would produce a hole having an inclined axis, such as Hole No. 1, cut out of horizontal strata.

---

* Water falling from great heights is often dissipated by the air which mingles with it during the fall; the cutting force of the water at the foot of a fall is directly proportional to the quantity of water and the height of the fall.

† This would undoubtedly be so where the hole was cut out of nearly horizontal strata, as in the case of Pot-hole No. 1. Where, however, the strata, out of which a hole should be cut, had a dip of only 5 degrees it can readily be understood how an inclined hole such as No. 1 could be cut by a vertical water-fall.


Map showing the position of the
"Cave" in the Ross Coal-bed workings
from the
Susquehanna Coal Company's Slope No. 1.
Scale 800 feet = 1 inch.
Approximate position of "Buried valley".
D.L.&W.R.R.
Station
Susquehanna
River
Breaker No. 1
Breaker No. 2
N.&W.B.R.R.
Back Water Pool
Slope No. 1
Nanticoke station
L.&S.R.R.
Slope No. 2
Coal Separator
Relief hole
Cave
800
400

Description of the Buried Valley of Newport Creek, near Nanticoke, with Special Reference to the Mine Accident of December 18, 1885.

One of the most unexpected and disastrous mining accidents which has occurred in the mines of the Wyoming valley, and in fact in the Anthracite Coal-fields, was the "*cave-in*" which took place in the roof of a portion of the Ross bed mine workings from Susquehanna Coal Company's Slope, No. 1, half a mile west of the town of Nanticoke, on the morning of December 18, 1885. The "*cave-in*" took place immediately under the culm pile from Breaker No. 2. The Engineering and Mining Journal, in a report of the accident, says:*

"The cave took place at the face of a short chamber almost at the face of a gangway, or, in other words, on the very edge of the 'solid' coal, and where no sign of danger of falls had shown itself or could have been expected. The water† that accompanied the flood of *débris* that in a few minutes filled the workings to the amount of about 100,000 cubic yards, was so small in quantity that it did not affect the pumps or noticeably increase the usual water of the mine, although in digging through the *débris*, boulders from one to two feet in diameter were met with, carried forward to a considerable height in the chambers by the flood."

"It is more than probable that all of the twenty-six men who lost their lives in this disaster were at once overwhelmed by the flood of culm and *débris*. Without clearing out the entire workings it is unlikely that all the bodies will be recovered, and the facts connected with the inundation of culm make it probable that there will be great danger to those employed in the work of recovering the bodies should the clearing out of the workings be continued."

---

*January 9, 1886.

† "The water that carried the culm, soil, and *débris* through the mine filling completely the gangways, and in part the chambers, for a distance of fully 8000 feet from the point where the 'cave' took place, was only the water in the culm and that in the *quicksands* that appear to have formed the roof over hat part of the mine."

I have made a careful examination of the ground in the vicinity of the "*cave-in*," with all the maps relating to the mines in the hands of the Susquehanna Coal Company placed at my disposal. A report will ultimately be prepared by Mr. G. M. Williams, MineInspector of the western end of the Wyoming valley, and published in the regular State Inspector's report; and it is only proposed to refer here to those special mining features connected with the accident which are concerned in a geological consideration of the causes to which the accident is to be attributed.

A review of all the facts, however, bearing upon the care with which mining in the vicinity of the "*cave-in*" has been prosecuted by the Susquehanna Coal Company, conclusively prove that the accident was unavoidable and could not have been anticipated by any measures which the company could have, with reason, adopted. This company, under the efficient management of the General Superintendent, Mr. Irving A. Stearns, and the Mining Engineer, Mr. J. H. Bówden, has been untiring in adopting every means to rescue the imprisoned miners, and, as far as I am informed from public records and from my personal knowledge of other mining accidents, no company in the anthracite coal-fields has exercised greater care in preventing accidents which might involve the lives of the miners, and has been more prompt and generous in all efforts to relieve the unfortunate, than the Susquehanna Coal Company.*

As is more especially referred to in Mr. Hill's report, prior to the glacial epoch the Susquehanna river flowed at a level 200± feet below the surface of the present Wyoming valley, and the valley has subsequently been filled with gravel and drift. Most of the shafts and bore-holes which have been sunk in the valley have encountered this drift, and its thickness has been determined at a number of points. A knowledge of these facts led the Susquehanna

---

*I have made this statement after a thorough investigation of the circumstances attending the accident, since in some of the published accounts at the time the accident took place, it was charged to ignorance on the part of the management of the company as to the proper support to give the rocks and the coal-culm piled on the top of the surface overlying the coal-bed.

the valley of Newport creek, in order to ascertain the thickness of the gravel, especially in that portion of the valley under which mining was about to be done, and where uncertainty might exist as to the thickness of solid rock which would form the roof of the coal mine, and the thickness of drift which might exist over this roof; a cave-in similar to that which occurred last December being anticipated in those areas where the drift was known to exist.

Most of the test drill-holes have been made in the valley of Newport creek, ahead of the mine workings in the Hillman and Mills beds, worked from shaft No. 1 and slope No. 2, the relative position of the culm-bank to the surrounding topography being such that it was never anticipated that a buried valley existed under its base. From all surface indications it was certainly the most improbable place to expect such a geological phenomenon.

The accompanying map page 626 shows the relative position of the "*cave-in*," the mine workings and the surface features. West from the south end of the Susquehanna Coal Company's coal separator building the buried valley of Newport creek has been clearly defined by the numerous bore-holes which have been drilled.* On the map is shown the position of bore-hole No. 38, the elevation of which is 555.1 feet,† the depth to the solid rock and the thickness of the drift was 100.75 feet, the elevation of the bottom of the buried valley under the hole being 454.35 feet. This hole, from its relation to the other holes on the west, must be very near the lowest point in the buried valley.

The most western hole drilled is about 50 feet north of where Newport creek crosses the west line of the Company's property, a little over half a mile due north of Newport Center. This hole is known as No. 14, and it is 5475 feet, south 70 degrees 15 minutes west from hole No. 38. The

*More than 200 bore-holes have been drilled by the company in the vicinity of Nanticoke in order to test the thickness of the drift in areas under which the coal-beds were to be mined.

†11.50 feet have been added to the elevations of the Susquehanna Coal Company in order to reduce them to the tidal datum adopted by the Geological Survey.

elevation of the top of the hole is 574.65 feet, the depth to the solid rock or the thickness of the drift is 103 feet, and the elevation of the bottom of the valley above tide at this hole, which would seem to be the lowest point in the valley, is 471.65 feet. The bottom of the buried valley from hole 14 to hole 38 falls 17 feet.

Between hole No. 14 and hole No. 38 the old buried valley follows in a general way the course of Newport creek, but the deepest part of the buried valley keeps to the north of the present creek.

In Mr. Hill's report on the buried valley in the vicinity of Wilkes Barre, he shows that at the Tripp Farm bore-hole, No. 1, south-east of "Harry E." breaker, and about 5 miles due north of Wilkes Barre court-house, the depth of the drift, or, as it is popularly called by the miners, the "*wash*," in the now buried valley of the Susquehanna river is 215 feet, the elevation of the bottom of the buried valley being 335 feet above tide. At the Woodward Farm bore-hole, No. 2, about half a mile north-east of the mouth of Toby's creek, and at a point about 2½ miles south-west of the Tripp Farm bore-hole, the depth of the drift is reported to be 202 feet,* the elevation of the bottom of the buried valley at this point being 318 feet above tide.

The elevation of the Susquehanna river at mean low water at Wilkes Barre is 516 feet above tide, and at mean high water 541 feet above tide, so that the old Wyoming valley, before it was filled up with the drift and gravel which now lie in its center, was about 200 feet deeper near Wilkes Barre† than the valley is at the present time.

The elevation of the Nanticoke dam across the Susquehanna river below the mouth of Harvey's creek is 514.76 feet, which is only a few feet lower than the mean elevation of the river at Wilkes Barre. It is fair to assume that the slope of the old Wyoming valley from Wilkes Barre to Nanticoke was at least as great as the fall of the present river, so that, since it is quite certain that the Susquehanna

---

*An element of uncertainty exists as regards the depth of the drift at the latter bore-hole.

† More nearly in the vicinity of Kingston.

the bottom of the old buried valley in this gap must be at least 205 feet below the surface of the Nanticoke dam.

It has been suggested that the Susquehanna river at one time flowed through an old valley, which is now buried by drift, south-west of Nanticoke, and found an outlet somewhere in the vicinity of Shickshinny. This, however, is an impossible hypothesis. The fact that the bottom of the old valley slopes from Bore-hole No. 14 north-east toward Bore-hole No. 38, together with a study of the facts, which may be readily had from an inspection of the topographical map accompanying this report, and from an examination of the ground, proves that a rock barrier exists all around the south-western end of the Wyoming valley, which would have prevented the river from getting out at an elevation approximate to 454 feet, which is the elevation of the bottom of the valley at Bore-hole No. 38, or 472 feet, which is the elevation of the bottom of the valley at Bore-hole No. 14.

The elevation of the Susquehanna river at Shickshinny is about 505 feet above tide, so that if the Susquehanna river at one time flowed immediately over the solid rock bed now forming the bottom of the buried valley, through the Wyoming valley, south-west of Nanticoke, there must be a cut through the rocks encircling the end of the valley, opposite Shickshinny, to a depth of 210 feet below the surface of the present river at Shickshinny. That such a cut did at one time exist, and which may have been subsequently filled by drift, an inspection of the topography and rock exposures on the ground absolutely disprove.

The fact that along a certain line through the Nanticoke Gap, at present undetermined, the drift must be 200 feet deep to the bottom of the buried valley at about an elevation of 310 feet above tide; when considered in conjunction with the facts already presented to prove that the buried valley of Newport creek must have had an outlet toward the north-east, are sufficient to warrant the assumption that the stream occupying the buried valley south-west of Nanticoke joined the Susquehanna river in front of the gap,

and that the river occupied the same general position in the gap as it does at the present time.

From the south end of the Susquehanna Coal Company's coal separator, to the Nanticoke Gap, we have no sufficiently precise data to exactly locate the bottom of the buried valley, in the same way that the bore-holes drilled to the south-west of the separator have permitted us to locate the bottom of the valley in that section. We have, however, sufficient facts to enable us to approximately locate it.

From Nanticoke Station, on the Lehigh and Susquehanna railroad, there is an almost continuous line of outcrops toward the south-east. About 700 feet north-west of this station is located the mule stable, or what is commonly known as the "*Red Barn*," of the Susquehanna Coal Company. In the vicinity of and to the north-west of this stable there are exposed rock outcrops. Between the stable and the station, however, there are no outcrops, and the buried valley no doubt lies between these two points. The exact location of the buried valley from a line between Breakers Nos. 2 and 5, through the gap, cannot be determined absolutely by the facts at present at our command. Rock outcrops are found north-west of Breaker No. 2 and south-east of Breaker No. 5.

A careful consideration, however, of all outcropping rocks in the Nanticoke gap, and of the bore-holes sunk by the Susquehanna Coal Company on the flat directly east of the Nanticoke Bridge, suggests two or three lines as the center of the buried valley.

Special reference to the location of the valley is deferred until a more detailed report on this subject, which it is proposed to make in conjunction with a careful topographical map now being constructed by the engineers of the Susquehanna Coal Company of the present surface of the Wyoming valley in the vicinity of Nanticoke. Additional records of bore-holes which the Company propose to drill will permit of the more satisfactory consideration of this subject.

It now remains to trace the buried valley from the southern end of the coal separator to a line between Nanticoke Station (L. & S. R. R.) and the "*Red Barn*." It is safe to

tion of the bottom of the valley in the Nanticoke gap is about 310 feet above tide, and the elevation of the bottom of the valley at Bore-hole No. 38 as 454 feet, so that between the coal separator and the gap there must have been a fall in the valley of 145 feet more or less. In locating the buried valley between these two points, an important question suggests itself for consideration, and that is, does the valley fall at an even grade in this distance of about 1 mile, or is the grade interrupted at one or more points by water-falls?

To the right of the county road leading from the Nanticoke Station (L. & S. R. R.) towards the coal separator, and about 100 feet east of the separator trestle-work, a bore-hole was drilled after the "*cave-in*" took place, as a relief measure. This bore-hole was located by the miners' relief committee and drilled by the company.*

The position of this hole is shown on the accompanying plate (page 626), as are also all the points to which reference is made in this report. The following is a record of the Relief bore-hole:

1. Soil, sand, etc.,	218′
2. Sandstone and slate,	53′ 10″
3. Open space,	2′ to 3′
4. Loose material,	2′ to 3′

At a depth of between 150 and 155 feet, water was encountered coming from the casing of the hole. The elevation of the top of the hole is about 656 feet, the elevation of the solid rock encountered in the hole is 438 feet. This

*This hole was drilled by the company, no doubt as all the other relief measures which they undertook, at the instance of the friends of the imprisoned miners, since it cannot be believed that any one familiar with the mine and the facts connected with the accident could have entertained any reasonable hope that the miners lived many hours after the cave-in took place; in fact, I am thoroughly convinced that the same force which within an hour brought material from the cave-in out to the mouth of the tunnel opening into Slope No. 1, carried similar material within a much shorter time into the rooms south and east of the cave-in, in which the imprisoned miners were supposed to have been at the time the accident took place, and I believe that all the men here entrapped were doubtless dead inside of an hour. It is unnecessary to review in this place the facts and circumstances connected with the accident which lead me to this conclusion.

hole must be very near the center of the buried valley, which evidently makes a sharp turn around the south end of the separator and passes over the mine workings in the vicinity of the bore-hole.

The slope of the bottom of the buried valley between Hole No. 38 and the Relief bore-hole must be at the rate of about 2 feet per hundred unless there was a water fall in the old stream occupying the buried valley between these two bore-holes. The buried valley must have approximately the position which is here suggested, since a rock exposure was found directly east of the point where the mine workings pass around the end of the anticlinal in coming from the "*cave-in*" around to the position of the Relief bore-hole. The elevation of the rock exposure at the point referred to is 575 feet above tide, or 139 feet above the solid rock first encountered in the Relief bore-hole.

In the vicinity of the "*cave in*" the buried valley doubtless makes a sharp turn and pursues a north-east course to a point between the Nanticoke Station and the "*Red Barn*" already referred to. The elevation of the top of the culm bank over the "*cave-in*" was 709 feet above tide, the elevation of the surface of the ground at the base of the culm bank is 662 feet, and the elevation of the roof of the coal mine under the "*cave-in*" at the point where the "*cave-in*" took place was 400 feet. The slate roof of the mine between the mine workings and the bottom of the drift in the "*cave-in*" at this point was probably 3 or 4 feet thick so that the elevation of the solid rock under the "*cave-in*" was probably about 405 feet above tide.

If the old buried valley had a gradual slope from the Relief bore-hole to the position of the "*cave-in*," the bottom of the valley sloped at the rate of nearly 7 feet in a hundred. How far this north-west course which has been suggested for the buried valley at this point continued, north-west of the "*cave-in*," it is impossible to surmise, since we have no facts bearing upon the location of the valley beyond the "*cave-in*." It is probable, however, that the valley made a sharp turn in the vicinity of the "*cave-in*," and from this turn had a more or less direct course to a

between the "*cave-in*" and a line between Breakers Nos. 2 and 5 the buried valley should have a regular slope, it would amount to about 4 feet in a hundred.

The creek which flowed in the buried valley, as it made a sharp turn in the vicinity of the "*cave-in*," must necessarily have produced a whirlpool in the water at this point. The diameter of this whirlpool and its depth would, of course, depend upon the amount of water flowing through the buried valley and the velocity which it had at the point where the turn was made in its course, both of which must have been considerable from the fact that the pool contained large rounded pebbles and boulders of rocks which were evidently whirled around in the pool by the force of the water. When the old valley was ultimately buried by being filled up by the drift which it contains, these boulders and pebbles were buried in the pool by the drift. When the "*cave-in*" took place a large mass of these boulders and pebbles were found in the gravel and soil which flowed into the mine and filled up a large part of the workings. A large number of these boulders were taken out of the mine workings by the relief workers, when the effort was made to get to the miners by working along the tops of the chambers of the mine workings.

If the pool had not existed in the bottom of the buried valley where the "*cave-in*" took place large boulders and pebbles would not have been found at this point in the valley, since there must have been a low point or "*sump*" to have held the boulders and pebbles which filled the mine at the time the "*cave-in*" took place, and which low point prevented the boulders and pebbles from being rolled down the Newport buried valley and into the ancient Susquehanna river flowing in the valley prior to the time that it was filled by drift.

As has already been said, it is impossible to determine, with the present facts at our hand, whether the grade in the bottom of the buried valley, from the end of the coal separator to the "*cave-in*," was a gradual one, or whether it was interrupted by rapids or falls at different points; in

fact, it is possible that the low grade in the bottom of the buried valley from Bore-hole No. 14 to Bore-hole No. 38 has continued at the same rate to the edge of the "*cave-in*," and, if this is so, there was a considerable water-fall in the old valley at the point of the "*cave-in*." In this case the "*cave-in*" might be classified under the head of a pot-hole. It would be different, however, from the Archbald pot-holes from the fact that it must have been formed in Pre-glacial Times rather than near the end of the Glacial Epoch, during which the Archbald pot-holes were evidently excavated. The sharp turn that the buried valley must have taken at or near the "*cave-in*," together with a number of other considerations, induce me to accept the former hypothesis, that is, that a whirlpool existed in the vicinity of the "*cave-in*" rather than a pot-hole.

The latter hypothesis has, however, been more generally accepted, although no special facts have been advanced by any one to support it.

The recent discovery of the Archbald pot-holes, and a likeness in the essential features of these holes to the Nanticoke "*cave-in*," have doubtless been the reasons why the pot-hole hypothesis has been suggested and generally accepted.

A careful study of the facts which I have presented in connection with these two geological phenomena, (the Archbald holes and the Nanticoke "*cave-in*,") together with those presented by Mr. Hill in his description of the buried valley, more particularly between Pittston and Kingston, should incite local geologists and miners to explore still further these geological problems which are so important in their practical bearings. They are certainly among the most important which the Geological Survey has to deal with in this region. Unfortunately, however, few facts can be obtained except through drill-holes or shafts, and the expense of such work is quite beyond the resources of the State Survey, which must depend upon the mining companies for such records. It is proposed to make a continued study of these phenomena as facts shall be obtained.

II.

Description of the Wyoming Buried Valley between Pittston and Kingston.

By Frank A. Hill.

The Susquehanna river, after breaking through the Lackawannock mountain, at Pittston, Luzerne county, flows along the southern borders of Exeter, Kingston, and Plymouth townships, again passes out through the same mountain at Nanticoke, continues along the southern border of Union township to Shickshinny. Here bending sharply south, it cuts its way through the conglomerate underlying the coal measures and flows on towards the town of Berwick, where it enters Columbia county.

The Lackawannock mountain* forms the northern border of the Wyoming coal-basin, so that the river enters this basin at Pittston, leaves it at Nanticoke, and crosses it again at Shickshinny. Along its course lies the Wyoming Buried Valley. Its history is one of the greatest interest, its present condition one worthy of study, while its future record will be largely dependent upon the influence of engineering foresight and skill.

The buried valley is the work of ages of erosion, an erosion which has obliterated at least three workable coal-beds from an unknown area, and cut a channel through the Wyoming basin greater in depth than the highest artificial point within its boundaries.

The study of this valley is one of the greatest economic importance, as its presence is a constant menace to life and property. The determination of its boundaries is a matter of vital importance to land owners, operators, and miners. Professor White has traced this ancient valley as far down

*This mountain, between Pittston and Nanticoke, is known as the Kingston mountain.

the river as Berwick, but it is especially within the boundaries of the Wyoming coal basin that these notes refer.

There are four drift plain areas, the topography of which must be especially noted in this connection.

1. The area which lies between West Pittston and the mouth of Toby's Eddy, at Kingston, and between the Susquehanna river on the south, and the foot of the Kingston mountain on the north. It is covered with drift and is generally flat, at no point rising more than 50 feet above the river level.

2. That along the south side of the river, bounded on the south by the Lehigh Valley railroad extending from Port Blanchard to three-quarters of a mile north-east of the mouth of Mill creek. The mine workings of the Wyoming, Henry, and Enterprise collieries honeycomb the Baltimore and Hillman beds under a large part of this area.

3. That along the north edge of the river lying south of the D., L. & W. R. R. and extending from the western end of the town of Plymouth to the Susquehanna Coal Company's breaker, No 3. This same area is continued on the opposite side of the river in the "Nanticoke flats," east of that town.

4. That on the south side of the river, extending through the city of Wilkes Barre and from the Fish Island bend, opposite the mouth of Toby's Eddy, to the mouth of Buttonwood creek, near Butzbach's landing. As it approaches its western end it is bounded on the south by the bluff along the south edge of Buttonwood creek. It at no point rises 02′ above the level of the river.

Within these areas there are no rock exposures, nothing, in fact, but the mining developments to give any idea of the true position of the bed rock.

Save where they are broken by streams, the river foot hills surround these flats on all sides, with outcrops of sandstones, slates, and coals in each plainly exposed.

There is great doubt as to the true position of the Buried Valley between Wyoming and its intersection with the present river at West Pittston. Wherever else its north edge has been developed it has been found close to the

mountain. This is possibly the case east of Wyoming, but the little information we possess indicates, I think, a circuitous and complicated course, well south of the foot of the mountain. The piers of the D., L. & W. R. R. bridge at West Pittston are not built on rock. The depth of "*wash*" here is about 50 feet. At the upper bridge between Pittston and West Pittston, on the eastern end, the rock is exposed at low water. The piers of the lower bridge between Pittston and West Pittston were built on cribs resting on gravel.

The Clear Spring shaft cut 54 feet of "*wash.*" The elevation of the top of this shaft is 562 feet.* The elevation of the bottom of the drift is therefore 508 feet or 30 feet below the present level of the river. At the Exeter shaft, at West Pittston, there is only 18 feet 8 inches of cribbing to the bed rock. This makes the bed rock higher than the present level of the river.

The Knight shaft cut 92 feet of "*wash.*" The elevation of the top of this shaft is 582 feet. The elevation of the bottom of the "*wash*" is therefore 490 feet, or about 50 feet below the present level of the river.

The Niagara shaft never reached bed rock, it being impossible to pump the water and quicksand as fast as it came into the shaft. It reached a depth of 82 feet before it was abandoned.

The Schooley main shaft was sunk through 110 feet of quicksand and loose material. The elevation of the top of this shaft is 562 feet and of the bottom of the drift 452 feet or 80 feet below the river level.

The Schooley air shaft was reported to have been sunk through 122 feet of "*strata*" before the rock corresponding to the bed rock in the main shaft was cut. This 122 feet of "*strata*" cut is described as "a very soft fire-clay resembling clay after being mixed with water." There was almost no sign of quicksand in this shaft, but judging from the description given me, I should think the "*strata*" cut was

---

*** All the elevations noted in this description are based on the tide datum of the Lehigh Valley Railroad, which is the generally accepted datum of all levels in the Wyoming valley. Many of the elevations are only approximate, that is, they may be 2 or 3 feet more or less than those reported to the Survey.**

a drift deposit. If this conclusion is correct, the Schooley shaft is not on the southern brink of the Buried Valley, as has been sometimes asserted; there seems to be nothing, however, in the vicinity of West Pittston which absolutely determines its southern boundary.

On the W. S. Shoemaker property, in the town of Wyoming, there are two bore-holes north of the "Back road," where the rock was cut at an elevation higher than the present level of the river. In a bore-hole on the same property, 200 feet south of the back road, 110 feet of drift was cut. The elevation of the top of this hole is 570 feet. The elevation of the bed rock is therefore 460 feet, or 70 feet below the present level of the river.

Another bore-hole, 150 feet north of the Coxton Branch of the L. V. R. R., cut 116 feet of "*wash.*" The elevation of the top of this hole is 555 feet, that of the bed rock 439 feet, or 91 feet below the present level of the river. Still another bore-hole, 200 yards south of the Wyoming road on the west side of Railroad street, cut 119 feet of "*wash.*" The elevation of the top of this hole is 570 feet. The bottom of the "*wash*" is therefore 451 feet, or 79 feet below the present level of the river. There is no rock exposed in this vicinity north of the river.

There are several bore-holes on the Pennsylvania Coal Company's property a little east of the last-mentioned hole, the records of which are not in possession of the Survey. They are said to have cut about the same thickness of "*wash*" as the Shoemaker holes. We have no official authority, however, for this statement.

On the Fuller Coal Company's property, one mile west of the town of Wyoming, a bore-hole has been sunk which cut 60 feet of "*wash.*" The elevation of the top of this hole is 570 feet, the elevation of the bed rock is, therefore, 510 feet, or 20 feet below the present level of the river.

In a bore-hole sunk 350 feet north of the D., L. & W. R. R., 60 feet of "*wash*" was found. The elevation of the top of this bore-hole is 550 feet, the elevation of the bed rock is, therefore, 490 feet, or 40 feet below the present level of the river. A bore-hole has also been sunk on the edge of the

Wyoming wagon road. The elevation of the top of this bore-hole is 540 feet, the depth of the "*wash*" is 80 feet, making the elevation of the bed rock 460 feet, or 70 feet below the present level of the river.

There is no rock exposed between the Fuller shaft and the river. In sinking the inside slope at the Fuller colliery a crevice was cut in the rock overlying the coal-bed, which brought in so much water that the colliery was flooded. The elevation of the coal-bed at this point is 400 feet, or 130 feet below the level of the present river.

From Pittston to the Fuller colliery the north edge of the buried valley has not been definitely outlined; the developments so far noted, however, would indicate that its deepest point was not far north of the river.

At the Maltby colliery its north edge is definitely determined by Shafts Nos. 1 and 2. The bed rock is cut at an elevation higher than the present river level. The workings in the Six-foot bed in No. 1 shaft were driven south into the "*wash*." (See Cross Section No. 26, Sheet No. IV, and Mine Sheet No. VII.) This point of contact is 280 feet south-east of Shaft No. 1, and clearly places the north edge of the buried valley between it and the shaft. This same shaft was sunk to the Eleven-foot bed, and, after driving down the dip (south-east) about 1300 feet, a rock plane was driven up at an angle of 20°, with the object of cutting the Six-foot bed. When this plane had been driven about 250 feet it was "*holed*" through into sand and water, which immediately flooded the mine and produced a surface cave having an area of ½ an acre.

An inside slope sunk south-east of Maltby No. 2 shaft in this bed 300 feet south of the *back road*, was obliged to leave the coal-bed and cut through the bottom slate owing to the bottom of the "*wash*" reaching to the top of the bed. The coal-bed is immediately overlaid by a "slaty shale." As the slope continues down the dip with sufficient covering for mining the point above referred to is evidently the lowest along the slope line. The elevation of the point where this bed, in Maltby No. 1 shaft, comes into contact with the "*wash*" is approximately 430 feet. This is about 100 feet below

No. 1 shaft workings where the "*wash*" was struck is at an elevation of 395 feet, 135 feet below the present river level. The elevation of the Eleven-foot bed in the slope, from shaft No. 2, where it touches the drift in the buried valley is 445 feet, or 85 feet below the present river level.

There are several bore-holes on the Maltby property held by the Lehigh Valley Coal Company which are not in the possession of the Survey. They may possibly throw some light on the southern edge of the buried valley. There is no rock exposure between the Maltby shaft on the north and the Susquehanna river on the south.

The Maltby sand shaft, just north of the Wyoming wagon road, was sunk into the drift but never reached bed rock.

At the Forty-Fort colliery the north edge of the old channel is located within a few feet by the shaft and the breaker bore-hole. There is 15 feet of "*wash*" cut in the shaft. This places the top of the bed rock above (probably 60 feet above) the present river level. The buried channel must necessarily be further south. The breaker bore-hole is 300 feet south of the shaft. The elevation of its top is 560 feet. The "*wash*" in this hole is 81 feet 4 inches in depth, making the elevation of the bed rock 479 feet, or about 50 feet below the present level of the river. This places the north edge of the buried valley north of this bore-hole, and consequently between it and the shaft. North of the D., L. & W. R. R., 540 feet, near the eastern boundary line of the Forty Fort property, is another bore-hole. The elevation of the top of this hole is 550 feet, the depth of the "*wash*" 144 feet 3 inches, making the elevation of the top of the bed rock 406 feet 9 inches, or about 125 feet below the present river level. There is no exposure of rock between this bore-hole and the river.

At the "Harry E." shaft, the top of which is 600 feet, there is about 85 feet of "*wash*." The elevation of the bed rock here is, therefore, 515 feet; approximately the same elevation as the present level of the river bed. Between the shaft and the D., L. & W. R. R. are the Tripp

Farm bore-holes. Tripp Farm bore-hole No. 3 on the line of dip is not more than 400 feet south-east of the shaft. The elevation of the top of this hole is 560 feet, the "*wash*" is 87 feet in depth, making the elevation of the bottom of the "*wash*" 473 feet, or about 52 feet below the present level of the river. This places the north edge of the buried valley between the No. 3 bore-hole and the "Harry E." shaft. Bore-holes Nos. 1 and 2 are between the D., L. & W. R. R. and the Bore-hole No. 3 above mentioned. They show the greatest development of drift (known to the Survey) in the Northern Coal-field. No. 1 shows 215 feet of "*wash.*" The elevation of the top of the "*wash*" is 550 feet, the elevation of the bottom is 335 feet, or 190 feet below the present level of the river. No. 2 shows 191 feet of sand and clay. The elevation of the top of this hole is 550 feet which would make the elevation of the bottom of the clay 359 feet, or 166+ feet below the level of the river.

At the Black Diamond colliery the new shaft was sunk through 105 feet of "*wash.*" The elevation of the top of this shaft is 560 feet. The elevation of the bottom of the "*wash*" is therefore 455 feet, or about 70 feet below the Susquehanna's present level. This shaft is evidently in the old bed of Toby's creek.

There is an outcrop of sandstone which overlies the Red Ash bed in Toby's creek, 3300 feet above the Black Diamond shaft, at an elevation of 575 feet, thus showing a fall in the old creek bed (if such it was) of 120 feet. The fall in the present creek between these two points is now 15 feet. East Boston shaft cut but 15 feet of drift. Pettibone shaft cut the rock at 82 feet. The top of the shaft by actual level is 21 feet above the river and at an elevation of 545 feet, the elevation of the bottom of the "*wash*" is 463 feet, or 60 feet below the present river level.

There is a bore-hole on the Lawrence Myers tract, on the Kingston flats, which is said to cut the bed rock at a depth of 69 feet. The elevation of the top of this hole is 545 feet, and of the bed rock 476, or 50 feet below the present level of the river.

Table of Elevations relating to Wyoming "Buried Valley."

Shafts, Bore-Holes, Etc.	Location.	Elevation of top.	Depth of drift.	Elevation, surface of "Buried Valley."	Below level of Susquehanna.
Clear Spring Shaft,	West Pittston,	562	54	508	30
Knight Shaft,	do.	562	92	490	50
Niagara Shaft,	do.	. . .	82		
Schooley Shaft,	do.	562	110	452	80
Schooley Air Shaft,	do.	.	122		
Shoemaker Bore-hole,	Wyoming,	570	110	460	70
Shoemaker Bore-hole,	do.	555	116	439	91
Shoemaker Bore-hole,	do.	570	119	451	79
Fuller Bore-hole,	do.	570	60	510	20
Fuller Bore-hole,	do.	550	60	490	40
Fuller Bore-hole,	do.	540	80	460	70
Fuller Colliery, (crevice cut in slope,)	do.	. . .	. . . .	400+	130
Maltby Shaft No. 1, (6-foot bed workings,)	Maltby,	. .	. . .	430	100
Maltby Shaft No. 1, (11-ft. bed rock plane,)	do.	. . .	. . . .	395	135
Maltby Shaft No. 2, (11-ft. bed slope, inside)	do.	. .	. . . .	445	85
Forty Fort Breaker Bore-hole,	Forty Fort,	560	81′ 4″	479	50
Forty Fort Bore-hole, near D. L. & W. R.R.	do.	550	144′ 3″	406′ 9″	125
"Harvey E" Shaft,	Luzerne boro',	600	85	515	10
Tripp Farm Bore-hole No. 1,	do.	540	215	325	190
Tripp Farm Bore-hole No. 2,	do.	550	191	359	166
Tripp Farm Bore-hole No. 3,	do.	560	87	473	52
Black Diamond New Shaft,	do.	560	106	454	70
Pettibone Shaft,	Kingston,	545	82	463	60
Bore-hole on Lawrence Myers' tract,	do.	545	69	476	50
Woodward Farm Bore-hole, No. 1,*	do.	525	160	365	145
Woodward Farm Bore-hole, No. 1,†	do.	525	40	485	25
Woodward Farm Bore-hole, No. 2,	do.	520	302	218	192
Highest point in Prospect or Henry Colliery workings north of river,	Kingston twp.,	. .	. . . .	. . . .	380
Nanticoke "Cave-in,"	Nanticoke,	662	257	405	110
Nanticoke Relief Bore-hole,	do.	656	218	438	77

* Record obtained from L. & W B. C. Co.

† Record obtained from I. A. Stearns, C. and M. E.

The elevation of the mouth of Toby's creek is about 510 feet.

The elevation of the top of the Woodward farm bore-hole, No. 1, is 525 feet, and is just at the foot of Ross' hill, which rises to the west and north-west very rapidly and exposes sandstones and slates (and a coal-bed) for at least 150 feet above the bore-hole. The depth of the hole to bed rock, according to the record obtained from the Lehigh and Wilkes Barre Coal Co., is 160 feet. This would make the elevation of the bottom of the "*wash*" 365 feet. Another record of this hole, obtained from Mr. I. A. Stearns, shows about 40 feet of "*wash*." This makes the elevation of the top of the bed rock 485 feet. If the L. & W. B. C. Co.'s record is correct, the bottom of the "*wash*" is 145 feet below the river. If Mr. Stearns' record is correct, it would be 25 feet below the river. This bore-hole, in connection with the exposures in Ross' hill, locates the northern edge of the Buried Valley within a few feet. The elevation of Woodward farm bore-hole, No. 2, is 520 feet. The depth of the "*wash*" is 202 feet, making the elevation of this point 318 feet, or 192 feet below the river. Near the mouth of Toby's creek, between it and the Wilkes Barre bridge, a channel has been cut in the river bed on the south-west side of Fish island, but no rock was encountered. There is no rock supporting the Wilkes Barre bridge piers.

For 1200 to 1500 feet below the mouth of Toby's creek the rock outcrop extends some distance into the river. There are no recorded developments,* either by drill or mining, on the broad flat extending from South Wilkes Barre to Butzbach's landing, neither are there any rock exposures within this area.

It will be noted that the above developments generally relate to the north edge of the Buried Valley. There are none to definitely determine the southern edge. On the southern side of the Susquehanna, from Pittston to the old canal basin at Wilkes Barre, there is an almost con-

*The only mining development in this vicinity is that at the Buttonwood shaft. This shaft is located near the southern edge of the river flat. There is no reliable record of its working extant.

river. These, however, are all lost here and do not appear on the north side of the river.

The workings of the Prospect and Henry collieries now extend across the river, the highest point developed north of the river in either of these collieries being at an elevation of 160 feet, 365 feet below the present level of the river, and 175 feet lower than the lowest point developed in the bore-holes further north.

There have already been several accidents from the contact of the mine workings with this hidden channel, all either fatal to life or destructive to property. The workings from a number of collieries are now approaching the Buried Valley areas. Whatever of risk there has been before will be multiplied proportionally by the number of new breasts and gangways that enter this comparatively unknown territory, while the possible shifting of the present river will add to the element of danger.

To guard against a hidden danger is always most difficult. Such a danger is here, and its avoidance is a question to be solved by the engineers and superintendents of the region.

III.

Description of a New Substance resembling Dopplerite from a Post-Glacial Peat Bog at Scranton.

By Professor Henry Carvill Lewis.

In the course of an excavation for a new court-house at Scranton, Pa., made July, 1880, a very interesting substance was discovered, specimens of which were sent to the writer at that time for investigation. The excavation cut through a peat bog, and it was at the bottom of this bog, some 25 feet from the surface of the ground, that the substance here referred to was found.

It appears that formerly there had been a lake or swamp at this place, which with the extension of the town had

been filled up. Below eight feet of cinder and other rubbish there is a bed of peat 10–12 feet in thickness. The peat is said to be a good fuel after drying. Beneath the peat is a deposit of "swamp muck," or carbonaceous mud, which dries to a hard compact gray mass, burning with difficulty. In this "muck" are numerous plant remains and occasional seeds.

The whole deposit rests upon glacial till or "hardpan," and is therefore of post-glacial origin.

Scranton is in the glaciated portion of the State, and the peat bog found here is one of the many which owe their origin to glacial causes. These peat bogs have been formed, for the most part, in former swamps or lakes caused by the damming up of streams by ridges of drift deposited at the time of the melting of the glacier.

Near the bottom of the Scranton peat bog are irregular veins filled with a black jelly-like substance, elastic to the touch. The veins of this substance, which are confined to the muck above described, vary in width from a mere stain to between two and three inches, and make all angles with the horizon, being frequently nearly perpendicular.

The substance, as thus found, has the following properties: When first taken from the ground it is jelly-like in consistency, breaking with a conchoidal fracture, and having a hardness of less than 1. Immediately on exposure to the air it becomes tougher and more elastic, resembling India rubber. It may be preserved in this condition if kept in alcohol. The substance is black by reflected light. When a thin slice cut by a knife is examined under the

---

[NOTE.—This paper was read by Professor Lewis before the American Philosophical Society, December 2, 1881, and is a carefully prepared and complete description of the mineral from the court-house excavation. The same mineral has since been found by Mr. Frank A. Hill in the excavation for the Young Men's Christian Association building, about 600 feet north-west of the court-house.

Attention was first called to this peat bog and the "*Dopplerite*" by Mr. John Tomlinson, of the Scranton *Times*, in a letter written by him to Mr. P. W. Sheafer, Geologist and Engineer of the Mines of Pottsville.

In this letter, from which I am permitted to quote, Mr. Tomlinson says: "I have sent you a sample taken from the muck or peat of a swamp in Scranton, which is being excavated to build the court-house. Formerly there was a lake in the spot, but as the town grew it was filled up with cinder and slag

microscope it appears brownish-red by transmitted light, and is nearly homogeneous in character.

Occasional seeds occur in this substance as well as in the surrounding peaty matter. In general appearance they resemble the seeds of certain *Cyperaceæ*. Under the microscope their surface is seen to be curiously marked with irregular wavy outlines. Professor J. T. Rothrock has been kind enough to make some sections of these seeds and reports concerning them that they have the character of spores of one of the higher cryptogams, probably *Marsilia*. He states that *Marsilia* is a bog plant, which is found during later geological time, and that the general shape and size of its fruit corresponds with that of the specimens under examination. The outer coat is made up of outwardly pointing prismatic columns, the extremities of which give the peculiar wavy appearance on the surface of these *peat seeds*. Yet, since the interior bag and its contents can be reduced neither to an embryo nor to the interior structure of the *Marsilia*, it is not possible to assign the seeds definitely to that species. No other recognizable organisms have been noticed in the substance here described.

The black jelly is tasteless and odorless. If placed in the flame of a Bunsen burner before drying, it burns

---

from the Lackawanna Iron and Coal Company's furnaces. In excavating for the foundation about twelve feet of cinder have been removed, and below this is found about fifteen feet of turf or peat, perfectly free from anything but vegetable matter, and which burns when partially dried precisely as Irish peat does. The specimen I send you is taken from a bog about two feet from the hard pan, or twenty-six feet below the surface. The vein of black formation which has excited great curiosity here stands perpendicu ar, so far as has been yet seen, and seems to be general over the area excavated at that depth. In some places it only amounts to a stain, but generally the black substance, is from half an inch to two and a half inches in thickness. It is the primary process of change from peat to coal. When first exposed to the air it is a stiff, jelly-like substance, with fractures when heated exactly like anthracite coal. Some of it has been dried and pulverized very easily to a fine dust."

At the request of Mr. Sheafer I forwarded a sample of the peat to Mr. Andrew S. McCreath, State Chemist, which was analyzed by his assistant, Mr. Stinson, on July 9th, and on the 16th I wrote Mr. Tomlinson, giving a general description of the probable method of the formation of the peat bog and the jelly-like substance which it contained.

The first published reference to this peat bog and mineral was made in the Scranton *Times*.—C. A. A.]

slowly and without flame. It is almost insoluble in water, alcohol, or ether, but is almost completely dissolved in caustic potash, and from the dark-brown solution thus formed may be precipitated in reddish-brown flocculent masses by the addition of an acid.

After exposure to the air until completely dry, the substance becomes brittle and nearly as hard as coal. In this condition it resembles jet or some of the varieties of lignite, and might readily be mistaken for those substances. It acquires a hardness of 2.5, and has the brilliant resinous luster and conchoidal fracture of the true coal.

It has a specific gravity of 1.032. It is jet black in the mass, but in powder is dark-brown. It now burns with a clear yellow flame. Soaking in water will not soften it appreciably. In the closed tube it gives off water and abundance of oil and empyreumatic vapors. The latter are in the form of a white smoke which can be lighted at the end of the tube.

In solubility it is like the undried substance. Hot alcohol dissolves a small portion, and forms a pale yellow solution. On treatment with caustic potash it dissolves completely, with the exception of an extremely slight residue of impurities. It will dissolve even in the cold. This test serves to distinguish the dried substance from brown coal or lignite, which are but partially soluble in alkalies.

A very slight trace of ammonia is given off on heating with caustic potash. By dissolving in a standard solution of alkali, and titrating with standard acid, it is found that the substance has an acid reaction. It is, therefore, an organic acid or a mixture of such acids.

The physical characters of this substance are closely allied to *Dopplerite*, but its chemical composition, as will be seen from its analysis, proves it to be an undescribed substance.

Mr. John M. Stinson, assistant chemist of the Survey, has made the following analysis. The substance was carefully separated from the surrounding earthy material, and dried at 212° F. before analysis. Carbon and hydrogen were determined in duplicate, the two determinations

Carbon,	28.989
Hydrogen,	5.172
Nitrogen,	2.456
Oxygen,	56.983
Ash,	6.400
	100.000

Approximate analysis of the dry separated material gave:

Volatile matter,	72.190
Fixed carbon,	21.410
Ash,	6.400
	100.000

Subtracting the amount of ash from the first analysis, we have:

C,	30.971
H,	5.526
O + N,	63.503
	100.000

From this we may deduce the empirical formula $C_{10}H_{22}O_{16}$. This formula would yield the calculated composition:

C,	30.15
H,	5.53
O + N,	64.32
	100.00

In giving the above formula it is by no means assumed that it represents a simple mineral substance. It is merely a convenient expression of its composition. It is probable that the substance here described is a complex organic acid containing water. The nitrogen may possibly exist as ammonia. The small amount of carbon and the excess of hydrogen distinguish this substance from other organic acids. By the subtraction of NH_4O, and one or more parts of H_2O from the formula, it may be more closely allied to some of the organic acids which form humic acid, the formula of which is so variously given by different authors. The determination of the true formula of the acid here an-

alyzed can only be determined after the formation of an organic salt with lead or silver. The absence of any exact knowledge concerning the composition of the organic acids existing in humus, as recently shown by Julien,* renders it difficult to express definitely the chemical relations of the substance under discussion.

The relation which it bears to its nearest ally, Dopplerite, may best be seen after a review of the facts as yet gathered about that curious mineral.

The mineral known by that name, and generally regarded as allied to humic acid, was first found in a peat bog near Aussee, Austria, at a depth of 6 to 8 feet below the surface. It was a black gelatinous substance, known by the peat-cutters as "*Moder-substanz*," which, after exposure to the air, became at first elastic and afterwards brittle, assuming the luster of coal. Döppler drew attention to this substance in a paper entitled, "On a Remarkable Gelatinous Substance Discovered in Austria," read before the Vienna Academy in 1849,† and stated that it was nearly insoluble in water, alcohol, and ether, but almost entirely dissolved by caustic potash.

Having been referred to Haidinger and Schrötter for further examination, it was fully described and named by them a week later. Schrötter‡ found its composition to be (after drying at 212° F.):

C,	48.06	or without ash.	
H,	4.98	C,	51.63
O,	40.07	H,	5.84
N,	1.03	O+N,	43.08
Ash,	5.86		

Haidinger named the substance and described its physical properties. He stated the observation of Löwe that it burned without flame, and that of Ettinghausen that it contained recognizable vegetable organisms.

In 1858 Gömbel§ announced that a substance very similar

*Proc. A. A. A. S., 1876, p. 311.

†Sitzunsb. d. k. Acad. d. Wiss. Wien, 1849, vol. i, p. 289.

‡ Loc. cit., p. 286.

§ Neues Jahr., f Min., 1858, p. 278.

Bavaria. Like the substance from Scranton, a black jelly-like substance was found as irregular and sometimes nearly vertical veins of varying, but slight thickness, in the lower part of the peat. It was known as Peat-Pitch-Coal. It was very slightly soluble in alcohol, giving it a pale yellow color, but was almost completely soluble in alkali. Unlike the original dopplerite, it burned with a yellow flame. Gömbel indicated the chemical changes which converted wood into peat, and showed that dopplerite had the same composition as peat, and was, in fact, a truly homogeneous peat.

In 1863 dopplerite was discovered in a peat-bog at Obburg, Switzerland, and was described by Kauffman, who, in an important paper,* showed that it had the same physical properties and chemical composition as the dopplerite of Aussee.

It occurred in a black peat at a depth of 12 to 14 feet in layers, sometimes a foot in thickness. Except in burning without flame, its physical properties were nearly identical with the Scranton substance. The air-dried dopplerite lost 19.7 per cent. of water at a heat of 110° C, and according to Muhlberg had the following composition:

C,	52.2
H,	5.9
O + N,	35.7
Ash,	5 2
	99.0

By dissolving in caustic potash, precipitating by acid, and then analyzing the dried precipitate, a similar composition was obtained. Kauffmann concludes that dopplerite consists of one or more of the humous acids, and shows that the portion of peat soluble in alkali is identical with dopplerite, and that compact peat contains minute black particles of dopplerite. Peat is therefore a mixture of dopplerite with partially decomposed plant remains; while dopplerite itself may be regarded as a homogeneous peat in

*Jahr., d. k. k. Geol. Reich, Wien. 1865, Vol. xv, p. 283.

which all organisms have been decomposed. He shows that in different peats the proportion of dopplerite, or part soluble in alkali, increases with the age of the peat, while the contrary is the case with mineral coal. Thus in a recent peat but 25–30 per cent. was soluble, in an old compact peat the proportion was 77 per cent. On the other hand, the solubility of coal decreases with its age, as shown in the following table, where the figures represent the degree of solubility in alkali:

(Dopplerite,)	(100)
"Slate coal," a woody lignite, Diluvial,	75
Brown coal,	42
"Pitch coal," Upper Miocene,	10
" Lower "	5
Bituminous coal, Eocene,	2.3
" " Carboniferous,	trace
Anthracite,	0

He concludes that in the formation of coal from peat, the first step of the process is the formation of dopplerite, and the second the gradual transformation of the latter into a material less soluble in alkali and richer in carbon.

Several other European localities for dopplerite have more recently been discovered.

A substance resembling dopplerite in the peat of Hägnetswyll, St. Gall, Switzerland, mentioned by Deicke,* burns with flame, and is regarded by Kenngott as having characters more nearly approaching those of Pyropissite or Melanchyme. It possibly is more analogous to the substance from Scranton.

Dopplerite has not as yet been discovered in America. While the substance described in the present paper more nearly resembles dopplerite than any other known mineral, it differs, as already shown, both in composition and in its behavior when burning.

A distinguishing feature of the Scranton mineral is its very low percentage of carbon. Dopplerite has almost the precise composition of peat, and peat, as is well known, contains more carbon than is contained in wood. Yet the Scranton mineral contains even less carbon than is contained

* Neues Jahr. f. Nim., 1858, p. 663.

gives a larger amount of hydrogen than is expressed in the formulas of any similar substance.†

A notice of this substance was given by Mr. T. Cooper, in the Engineering and Mining Journal, Aug. 13, 1881. A week later Mr. C. A. Ashburner contributed to the same Journal the following analysis, made by Mr. J. M. Stinson:

Water at 212°,	66.758
Volatile matter,	9.826
Fixed carbon,	4.012
Ash,	19.404
	100.000

Mr. Stinson informs the writer that this analysis was made of a sample consisting of a mixture of peat, muck, and the jelly-like substance, and that as no attempt was made to separate the latter, the analysis is not of scientific value.

Special interest is attached to the substance here described as being perhaps an intermediate product between peat and coal. While the quaternary lignites illustrate the transformation of wood with coal, this substance illustrates a similar change from peat. As, by the investigations of Kauffman, it was shown that the formation of dopplerite preceded that of any of the varieties of coal, so in the present case we have perhaps a yet earlier stage.

The characters of the Scranton mineral entitle it to a di tinctive place among the hydrocarbons of natural orig It has been the custom among mineralogists to regard tl substances as mineral species. In view, however, of objection to adding new mineral species whose distir

*The composition of peat is about:

C	H	O + N	Ash.
61	6	33	

The average composi'ion of wood is:

C	H	O + N	Ash
49.6	6.1	43.1	1.'

v. Coal, its History and Uses. Thorpe, etc., p. 165.

† The formula of dopplerite has been given as:

C_{40}	H_{25}	O_{25}	(Gmelin);
C_{16}	H_{10}	O_{10}	(Descloise
C_{10}	H_{6}	O_{5}	(Dana.)

characters are made prominent only by analysis, the writer believes that it would be more advisable to combine those already described under generic names, and to regard the minerals included in such genera as varieties.

In the present case we have to do with a black jelly-like substance derived from vegetable decomposition, which, with a different composition and with somewhat different physical properties, has been found in similar geological conditions in several parts of Europe. It is therefore suggested that all of these substances be combined under one generic name. The name "*Phytocollite*" (φυτὸν, κόλλα) signifying "plant-jelly," would include all jelly-like substances formed by the decomposition of plant matter. Dopplerite would then be regarded as one of its varieties, the mineral described by Diecke would be another, and the mineral from Scranton yet another.

Some general considerations of the pressure, quantity, composition, and fuel-value of rock-gas or the natural gas of the oil regions of Pennsylvania.

By J. P. Lesley.

1. *Rock-gas pressure.*

The condition of the underground world of rocks varies with the internal constitution of its beds.

A bed of plastic clay yielding to the pressure of its own weight will adjust itself upon its bed everywhere alike, and fill up any vacancies produced by chemical or mechanical solution, or by movements in its bed. Consequently no percolation of its fluids is possible through a plastic clay-bed; it will absorb a certain amount of fluids and retain them.*

On the contrary, a stratum of quartz-conglomerate cemented by clay may have all its clay-cement washed out of it without re-adjusting its bulk beyond what movement s necessary to cause all its pebbles to touch and support each other. In this condition a bed of quartz-pebbles can ustain the weight of a great height of country above it. n getting into this condition the pebbles will move upon ach other because of their different sizes, and some of them will be fractured because of different hardness and soft-ess, but, in the end, all will come to rest, supporting each ther and the country above.

The size of the pebbles is of no account in the general tatement. They may be as large as cannon balls, or as mall as a pin's head. If they all touch, the stratum will

*By percolation is meant here a sensible flow. In the true sense of the term ercolation is possible and actual through all rocks, and the soaking of clay can ly take place by this insensible percolation. Water has been found free in hollow cretaceous flint embedded in later gravel beds. (See Meunier's de-ription, quoted in Amer. Nat., Aug., 1885, p. 794.)

Table of Water and Rock-pressures.

Vertical height of strata in feet.	*Water (fresh).* *Weight per □'' in lbs.*	*Water (fresh).* *Weight per □' in long tons.*	*Sandstone and shale.** *Weight per □' in long tons.†*
1′	0.433	0.027	0.0725
100′	43.285	2.782	7.25
1000′	433 lbs.	27.82	72.50
1100′	476 "	30.60	79.75
1200′	519 "	33.38	87.00
1300′	563 "	36.17	94.25
1400′	606 "	38.95	101.50
1500′	649 "	41.73	106.75
1600′	693 "	44.51	116.00
1700′	736 "	47.29	123.25
1800′	779 "	50.08	130.50
1900′	822 "	52.86	137.75
2000′	866 "	55.64	145.00
2100′	909 "	58.42	153.25
2200′	952 "	61.20	160.50
2300′	995 "	64.00	167.75
2400′	1039 "	66.77	175.00
2500′	1082 "	69.55	182.25
2600′	1125 "	72.33	189.50
2700′	1168 "	75.11	196.75
2800′	1212 "	77.90	204.00
2900′	1255 "	80.68	211.25
3000′	1299 "	83.46	218.50
3100′	1342 "	86.24	225.75
3200′	1385 "	89.02	233.00
3300′	1428 "	91.80	240.25
3400′	1471 "	94.58	247.50
3500′	1534 "	97.36	254.75

* Average specific gravity assumed at 2.60.

† Or atmospheres, the weight of the atmosphere being about one ton to the

be at rest—able to support the country above—and yet permit the percolation of fluids between them.

The shape of the pebbles is of account only to the process of adjustment. If they are all originally round, the only movement necessary is that which brings them together. If they are angular, and the pressure exceeds the breaking-strength of the material, they will have their points and edges crushed off, and they will thus be reduced to a round form.

The stability of a conglomerate bed, then, depends on three elements: 1, the weight of country above it; 2, the strength of the pebble stuff; 3, the kind of cement in which the pebbles were originally embedded.

1. The weight of super-rocks in Western Pennsylvania, where everything lies flat, and most of the rocks are sandstone and shale, may be taken at 1 ton per square foot for every 14 feet of height,* or 100 tons for 1400 feet, a common depth of oil wells, or 200 tons for 2800 feet, which is not the maximum for the very deep wells.

2. Most rocks will bear a far greater weight without crushing, but they begin to crack and break at about half their crushing load. The *average* ultimate crushing load of brick is 175† tons to the square foot; of brown sandstone, 200; gray sandstone, 300‡; limestone, 425§; granite, 600‖; best glass, 1800,¶ (Trautwine.)

The quartz-pebbles of a conglomerate touching each other would undoubtedly crack each other under a weight of 1000 tons to the square foot; but, to be subjected to this

*The atmosphere at sea level weighs about 14¾ pounds (avoir.) per square inch, or 2124 pounds per square foot, say a ton. Fresh water weighs 62¼ (not 2½) pounds per cubic foot; salt water, 64; soft brick, 100; hard brick, 125; est pressed brick, 150; dry potter's clay, 156; mud pressed into a box, 110 to 0; gravel or sand equally, if dry, 90 to 120, if wet, 120 to 140; sandstone, 150; hale, 162; slate, 175; limestone, 168 to 172; coal, 84; (anthracite, 93.5.) The verage weight of carboniferous and sub-carboniferous strata may be safely ssumed at 162 pounds to the square foot, per square foot of height = 1 ton 2,240 lbs.) per 14 feet high.

†,50 to 300. ‡ 150 to 450. § And marble, 250 to 600. ‖ And syenites, 0 to 300. ¶ 1300 to 2300.

pressure they must lie ($5 \times 2800' -$) 14,000 feet beneath the surface.*

3. The cement of a quartz-pebble conglomerate is usually siliceous ; that of a quartzite is always so. In this case the pebbles are supported by the cement, and very little supported on their points of contact with each other. The whole is a solid mass, and the maximum of resistance to the crushing weight is reached. No fluid percolation is in this case possible ; no dissolution of the clay part of the cement ; no production of porosity in the rock ; no weakening of its strength.

But most of our sandstones are deposits of sand-grains in clay, parts of the bed being more sand than clay ; other parts more clay than sand ; sand-banks passing sideways into mud-flats, and coarse sands overlying and overlaid by fine sands and muds. Streaks of pebbles run through the mass, showing where the ancient water-currents ran, and these determine the existing underground drainage. This underground drainage, following the looser pebbly stretches in the rock, slowly dissolve the clay and carry it off, leaving the rock porous, and the drainage enlarges itself by attacking the tighter portions of the stratum, making it also more or less porous. Thus have come about our loose oil-sands. The process is hastened wherever the mud-cement is calcareous, chemical solution assisting the mechanical solution.

The cement-clay being removed, the pebbles or grains of quartz-sand resting against each other hold up the country, which weighs, if 2800 feet deep, 200 tons to the square foot. They are not crushed, because each quartz-grain or pebble, if square, can bear from six to nine times that weight, and even when round can bear several times that weight.†

Enough that there is not overweight enough to crush up

* The slickensides in conglomerates and slates, and the brecciated and rotated condition of crystalline limestones and marbles, have been produced by a combination of constant weight with occasional upheavals. Readjustment has left such traces in strata of every age ; most in the oldest.

† It would be impossible to calculate the proportion, because the strain would vary with the shape and constitution of every pebble or grain in the

the pebbles and destroy the porosity of the rock. Fluids and gases can freely circulate through it, subject to none of the pressure of the overlying country, all of which is supported by the porous rock itself.

Any pressure, therefore, which water, oil, or gas may exhibit at a depth of 2800 feet, for example, must be entirely independent of the weight of the country. If connected with the surface, the waters and gases must obey the laws of hydrostatic pressure; the water, if separate, must be under a pressure of ($62\frac{1}{2} \times 2800 =$) 78 tons (or atmospheres) to the square foot, and the gas, if separate, must lie under a pressure of between 1 and 2 tons or atmospheres. These are the greatest natural pressures to which their shut-in situation naturally subjects them. If they exhibit greater pressure it must be owing to something entirely apart from the depth in the earth where they lie.

But if there be no connection with the surface waters and air, there is nothing in the mere depth of their residence to put them under any special pressure whatever. They might even lie in a vacuum.* For the pebbles and grains among which they move can bring no pressure to bear on them, any more than the walls of a cave can press upon the underground river which flows through it; or the pillars of a mine can compress the gunpowder smoke of the miners.

Why is it, then, that a McKean county gas well blows off at a surface pressure of 575 pounds† to the square inch, (equal to 36 atmospheres,) and must of course be under a still greater pressure at the bottom of the tubing?

Hydraulic pressure can have nothing to do with it; for n a 2000′ well the water pressure is about 60 atmospheres at the bottom, decreasing to 0 at the top. Yet at the top he gas is blowing off at a pressure of 35 atmospheres. There is no great artesian head in the surrounding highland, which is only a few hundred feet higher and produces no copious springs.

Evidently the gas must in some way produce its own

---

* As the water does in many bubbles in opals, and in crystals of quartz in metamorphic rocks.

† Carll's report, p. 39.

pressure; like gas generated by chemical reaction in a closed vessel. Any elasticity in the vessel (an Indian rubber bag for instance) would moderate the pressure by yielding to it; but there is no elasticity in the rock-reservoirs in which natural gas is generated.

Although the gas-pressure cannot be in any way generated by the weight of the country, yet were it possible for it to exceed that weight, it must lift the country, float it off its supports, break it, escape into the air through the rents, and let the country drop back again upon its supports. There is, however, no evidence that this has happened, and no evidence that the gas-pressure is anywhere equal to half the weight of the overlying country.* But whatever it may be, so long as there is no vent for it, it must exert itself against its surroundings, and in doing so must lighten *by just that much* the weight of the country upon the gas-rock bed.

It is evident, also, that the gas must exert its pressure against whatever water or oil exists in the gas-rock, driving them before it to the surface by any vents, natural or artificial, which may exist. But in doing so it must in all cases exert a pressure greater than that of a hydraulic column from the surface down to the gas rock. The spouting oil wells have all been operated by natural gas, both in cases where the gas was mixed with oil and water, and in cases where it was banked in behind them and did not flow from the well until its oil and water were exhausted.†

---

* The Murraysville first well was 1320′ deep. The weight of country upon the gas-rock is about 100 atmospheres, (tons to the square foot.) The gas pressure at the surface is certainly not higher than 30 atmospheres, (500 lbs.: 1 ′.) How much greater it is in the gas-rock cannot be known, for that must depend on the rate at which it can deliver itself through the rock into the well.

† The Murraysville *gas-belt*, at the south end, towards the P. R. R., is continued as a *salt-water belt*. Wells at the R. R. spout water, not gas. This is one of many instances proving the fact that the gas separates itself into geographical areas and acts and is reacted on by water pressure. The wells at Pittsburgh and elsewhere have produced gas, which was afterwards stopped by an inrush of water. An enormous quantity of water was delivered by the Boyd's Hill well, overlooking the R. R. depot in Pittsburgh, (begun in 1876, and reaching 2300′ in January, 1877.) *Strong brine*, 3000 to 4000 bbls. per day, flowed from the "great gas rock," 1588′–1700′ beneath the surface; but no gas; and merely traces of oil. (L. 229.)

observed in any gas well has been 750 pounds.* This can only be asserted of pressures tested at the well mouth, or by the *packers* placed in the well.†

The best test is afforded by the height to which water is spouted into the air. In one case a 2000′ well spouted water 138′ into the air, showing a gas pressure of at least 60 atmospheres, (=about 940 lbs. to the square inch,) at the bottom of the well.‡

In another case the jets from a 1785′ well, recurring every 6 m., 55 sec., (39 jets in 4″ 36¾,) rose from 85′ to 115′, showing a pressure of at least 53 atmospheres (= 830 lbs. per sq. inch.)§

---

*S. R. Dresser, in *Petroleum Age*, March, 1886, p. 1279. "I have made this a subject of personal inquiry, as I furnish a good share of the *packers* used to confine gas." "I have never heard of any one who knows of any well gathering 1000 lbs. pressure." "There has never been a gas well struck so strong but what it could be tubed and packed; and when the tubing is securely anchored down to the derrick, a stop-cock or throttle can be closed and the flow of the gas confined." He then refers inquirers to companies in Bradford, Warren, Oil City, Rochester, Pa., Pittsburgh, and Findlay, O., who have secured their gas by packing.

† Dr. Orton, State Geologist of Ohio, whose report on rock-oil and gas is ready for publication, entertains grave doubts of the correctness of the reported pressures at the well mouths.

‡ The Ernhout & Taylor well, No. 2, Wetmore township, McKean county; begun March, 1878; struck oil rock May, 1878, at 1990′; oil not sufficient; casing withdrawn; well flooded with fresh water from veins; water ejected at regular intervals to about 125′ in the air; hole then partially plugged; eruptions of 2 minutes at regular intervals of 11 minutes. In July, 1879, Mr. Ashburner made a series of angular and watch measurements, which are tabulated in Report R,*p. 247. The phenomenon repeated itself thus: Slight explosion heard in the drive pipe; silence 2½ minutes; water began to flow; in ¼ minute reached its maximum height of 85′; column lowered, and in ½ minute rose again to 95′; in ¼ minute flow ceased; gas issued for 6¾ minutes. The next explosion commenced 11¼ minutes after the commencement (or 6¾ minutes after the end) of the first; and so on with great regularity, the jet varying from 75′ to 95′ in height. But, on the evening of July 31, two jets were measured which rose to 120′ and 128′; and Aug. 2, four jets were measured, which rose 108′, 132′, 120′, 138′. (See picture of a jet on p. 248 R.)

§ Wilcox well, No. 1, (Adams well,) on the W. br. Clarion river, a mile N. of the McKean-Elk line, 1864? Abandoned at 1785′; only 100 bbls. of oil pumped from it. It became famous in 1877 for its 7 minute jets of *mixed gas and water*. A great water vein had been struck at 60′, and gas veins at 1200′ and at 1600′. After the loss of the tools the upper 400′ was cased (4′) with a seed bag, making the well a dry hole, but a great gas blower. Gas used in

It must be considered, however, that no gas well throws into the air a column of water in the common condition of water, weighing as much as water. The jet consists of a foaming mass of water and gas mixed, just as a volcanic geyser ejects a column of mixed water and steam. The intermittent action and violent explosion are due to this fact. In the case of the geyser part of the water flashes into steam and blows out the rest of the water mixed with steam. In the case of the gas well the high pressure gas plays the same *rôle*. But, in spite of this apparent defect, the calculation must be, in the main, correct; for, what the weight lifted loses by being lightened by gas, it gains by friction in the pipe at high velocities, and still more by the *vis inertiæ* of the air and friction through the air.

The question of how far the hydraulic head may account for the gas-well pressure (on purely artesian principles) deserves and is receiving attention. But those who especially favor this theory must not ignore, as they are probably well aware, the *unknown factors in the problem*, viz: the distances and methods of connection with the surface; the rate at which the water-flow, and consequently the water-pressure, is transmitted down hill from the outcrop head to the well bottom in the deep; the stoppages of the water-way here and there by tight rock; the interposition of mud cracks across the water-way, &c. To get the observed pressure at Pittsburgh, for example, one must go for a high-head outcrop as far north as Venango county; but the porous oil-rocks do not extend continuously that far; nor

---

drilling No. 2; surplus gas (2″ pipe) allowed to flow into a water tank; ice formed in the hottest weather. From 1864? to 1876 gas flow constant (probably diminishing.) Well No. 2 showed some oil. To force it out a 2″ gas pipe from well No. 1 was lowered to bottom of No. 2, (2000; well, 2004 deep,) when gas-flow from both wells ceased for 36 hours, then began again with greater energy. Jan. 1877, gas pressure suddenly increased; upper 175′ of casing broke and was lifted bodily, with the plug, out of the No. 1 well, letting in the water vein. The well became again a geyser, jetting every 8 minutes 80′ to 90′, until the following May, when both wells stopped gasing for no known cause. July 14, No. 1 began again to spout every 7 minutes 85′ to 115′ jets, with intermediate little jets 3′ to 8′ high. Water and gas intermixed, and, when set on fire, magnificent. July 19, studied by C. A. Ashburner for the Survey and the results tabulated. (See Report R., p. 155.)

is any water-bearing stratum known to be continuous a su ficient distance to answer the requirements.* Nor can a nearer local head be assumed with any confidence, because the water-flow in that case must be vertical.

Friction in a pipe line is estimated to reduce gas pressure at the rate of about 7 lbs. per mile.†

In doing this it reduces the theoretical rate of velocity with which gas would deliver from the free mouth of any section of a pipe.‡

---

*The differenceof level between the top of the Third Oil Sand at Tidioute in Warren, and Clintonville in Venango, is (1008′ — 230′ =) 778′ in 89 miles; between Shippensville in Clarion and Herman in Butler, (370 + 500 =) 870′ in 85 miles. The first along the Venango belt; the second along the Butler belt. (See Mr. J. T. Carll's triangle dip map, sheet No. 6, in atlas to Report of Progress III, on the Oil Regions, 1880.) The first gives a hydraulic pressure of 335 lbs., the second of 374 lbs. to the square inch at the south-west end of the belt. Now, at Tidioute the Third Sand is only (1112′—1008′) 104′ beneath the river, but at Shippensville the Third Sand is (1400′± — 370′ =) 1030′± beneath the surface; and further on (north-east) the surface rises 1000 higher. If there were an *open water-bearing stratum all the way from Elk county to Shippensville*, the hydraulic pressure there should be 860 lbs. to the inch; and if that water-way were continued into Butler county, the theoretical pressure at Herman should rise to 1234 lbs., a force capable of lifting 1100 ft. of the earth's crust. But who can believe in such continuous open waterways for such distances in an old formation like the coal measures? The artesian wells of Paris are fed from a head on the slope of the Cote d'Or many miles distant to the south, but they are in loose strata of a late age. In like manner the artesian wells of New Jersey are fed from outcrops facing the Delaware river, but the beds are loose sands of tertiary and upper cretaceous age. No such state of things is known in the underground of our western coal measures. The oil sands alone can operate in this way, and they are restricted to long narrow areas with impervious walls; at least sufficiently impervious to practically stop the water-flow, and, if so, then, tapping the pressure anywhere must be immediately followed by a sensible decline of hydraulic pressure. We know that the oil and water do not pass up and down from one sandrock to another, therefore a direct hydraulic connection with the surface must be practically out of the question.

†Consequently, a 200 lb. pressure at the well will only deliver gas to a distance of 80 miles, if the delivery be constant. This settles the question of the delivery of gas on the seaboard. (Rept. Cham. Com. Pitts., p. 85.)

‡Smeaton's table of *wind pressure* (defective as its basis is considered by Trautwine) gives for a pressure of 50 lbs. per square foot (=3½ lbs. per sq. inch) a wind *velocity* of 146.7 per second. The pressure is generally supposed to vary as the square of the velocity. The Liverpool observations double Smeaton's pressures, a wind of *33 miles per hour* exerting a pressure of 1¼ lbs. per *square foot*; and one of 70 miles, 42 lbs. This would make the wind pressure = square of velocity divided by 100. If gas issues from a pipe at 500

The pressure is theoretically equal over the whole area of bed-rock occupied by gas, except in the vicinity of the bottom of each blowing well. If the gauges of different wells show different pressures, it must be for one or both of two reasons: 1. Greater friction due to extra smallness or extra length of well; or, 2. Greater friction in the converging movement of the gas through the rock towards the bottom of a well.*

2. *Rock-gas quantity.*

The quantity of condensed gas underground must be judged by the quantity of *expanded gas* furnished to con-

---

lbs. to the sq. inch (=72,000 lbs. to the sq. foot) its theoretical velocity should be (by the wind formula) 2700 miles per hour (=4000′ per second,) which is a rate only reached in cannon-firing, the initial velocity of the old 32-lb. ball being 1600′ per second. The wind formula, however, is only applicable to the free-moving atmosphere, with a low friction ratio. The gas-blow has a high friction ratio, strongly pronounced by its roar; like that of steam from an escape valve. No experiments have been made with solid projectiles from gas wells; but the projection of water into the air has been studied by the Geological Survey in two instances: the rise of the water column from the Wilcox geyser well, in McKean county, was timed: 101′ in 15 seconds; 99′ in 60; 87′ in 60; 87′ in 45; 83′ in 30; 99′ in ?; 86′ in 30; 91′ in 30; 115′ in 40; 97′ in 35; =average of 94′ in 53 seconds; representing a probable theoretical maximum initial velocity of say 10′ per second. But this affords no clue to the theoretical maximum initial velocity of the gas causing the jet.

Mr. Carnegie states the pressure of the great Murraysville 30,000,000′ well at nearly or quite 200 lb. One of the gauges showed him 187 lbs. At works nine miles from a well, the pressure was delivered at 75 lb. At one well the gas was used instead of steam in a small pumping engine.

*In October, 1885, a well was put down within 100′ of the largest Murraysville well. Its immense blow should have lowered the discharge pressure of the big well by a considerable percentage if the gas passed freely through the bed rock. The report was that "the volume of the old well was not affected in the least." (Eng. and Min. J., p. 310.) The report may have been only approximately true; but it is evident that two such wells, so near each other, cannot be indifferent to each other's discharge, within small limits of variation, unless, first, the pressure in the rock be vastly greater than the pressure at the well mouth; nor unless, second, the friction in the rock be a large factor in the equation. In early March, 1886, two new wells (Phila. Co. and Chartiers Co.) were struck, in close proximity to each other, and both reported to be equal to the best in the (Murraysville) district, (Eng. and M. J., p. 197;) but the reported pressure-tests at new wells must always be accepted with suspicion. More recently, it is reported that the Tarentum well pressure has diminished 30 or 40 per cent., and the conjecture hazarded that the flow is obstructed by the crystallization of salt; but the readiest explanation may be easier adopted, that the gas in the rock is exhausting itself.

burgh, were said to furnish from all their
1886,) 12,000,000 cubic feet per day.*

The waste of gas within piping distance
was estimated, in 1885, at 70,000,000 cubic f

Water absorbs its own volume of carbonic
any pressure; *i. e.*, whether the gas is at its
under one atmosphere or condensed to do
under two atmospheres.‡ It absorbs olifiant
to the extent of only one seventh of its ow
this law should hold good for all pressures it
that water under 750 lbs. to the inch (or 750
mospheres) would hold (.02 × 50 =) its own
fiant gas at one atmosphere. This is an insig
tity compared with the quantities of natura
off from a gas well. The well gas cannot,
(by occlusion) in the water. It must theref
be held in the form of petroleum or (2) be its
liquid under the highest pressures, or else (3

---

* Eng. and Min. J., March 27, 1886, p. 236. A flow at th
4,380,000,000′ per annum; occupying, at the ordinary pres
phere, 1 sq. mile × 40′; when condensed under 60 atmospher
or, a sand rock (⅓ porous) 1 sq. mile × 4′ thick.

† At a meeting of the Chamber of Commerce. See Repo
mated to equal in value of coal $3500 per day. Mr. Carn
1885, that up to that date only two concerns in Pittsburgh h
to economize the gas. In his Union Iron Mills, a small re
ance had been attached to each puddling furnace, saving a
In domestic use, also, some disastrous cellar explosions have
panies to use lower pressures in the city mains and to estab
to the surface air at frequent intervals. In manufacturin
which carry the gas-pipes overhead in open air no explosion
uary, 1886, the Philadelphia Nat. Gas Co., at Pittsburgh, is
mill men and manufacturers in regard to waste. Many mil
1″ and 1½″ pipes, perforated at the top, and the pressure su
than it can be consumed. In fact, one of these pipes would
steam boiler. Consumers were notified that no such light
lowed except from 4, P. M., to 6, A. M. The gross income of t
said to be, at that date, approaching $2,000,000 per annum.
Jan. 16, 1886, page 42.)

‡ Henry, in *Amer. Cyc.*, p. 84a, Gas. Cyanogen, 4.5 volume
gen, 3.66; chlorine, 2.00; carb. acid, 1.06; nitrous oxide, 0.
0.158; phosp. hyd., 0.05; nitric ox., 0.037; oxygen, 0.067; nitr
bonic oxide and hydrogen, only 0.02.

greatly condensed gas under a pressure of many atmospheres.*

Dr. Chance has published the following calculation for getting some idea of the possible quantity of gas held in a given area of rock:

Pressure, say 750 lbs. per inch (50 atmospheres.)

Thickness of porous part of rock, say 30′.

Porosity, say $\frac{1}{6}$ of the rock = 5′ of thickness.

Area, say 1 square mile, = 27,878,400 square feet.

This multiplied by 5′ gives the space occupied by the gas, = 139,392,000 cub. ft.; and this multiplied by 50 (volumes of gas condensed into one) gives total amount of gas in bed rock, say 7,000,000,000 cubic feet per square mile. One well blowing ten million per day would exhaust a mile in two years; and twelve wells would do it in two months.

Evidently the premises of the calculation above adopted do not correspond with the facts. Therefore, either the underground pressures are very much higher than gauges at the well-mouths show, or the thickness of porous rock is much greater than 30′. The whole rock (known to be sometimes 100′ thick) may be porous to gas.

Suppose the average porosity of 100′ sandrock to be $\frac{1}{8}$,

---

*Dr. Chance, in denying the possibility of gas in liquid form, uses the convenient formula: Rock weighs 144 lbs. per cubic foot; *i. e.*, 1 lb. per inch per foot of height, or 1500 lbs. (100 atmospheres) per 1500′ of strata. He argues rightly that, under 750′ of strata, the gas pressure cannot be greater than 750 lbs. to the square inch, and concludes that no great blowing wells need be looked for except in districts where the wells are deep. He argues that the gas cannot exist in liquid form because it consists mainly of marsh gas. 60 per cent. to 80 per cent., hydrogen, 5 per cent. to 20 per cent., and nitrogen 1 per cent. to 12 per cent., none of which can be liquefied under the conditions. Marsh gas, the most easily liquefied of the three, can only be liquefied under a pressure of 50 atmospheres by reducing the temperature to 99.5° *below zero* centigrade (− 148° F.) or under a pressure of 180 atmospheres at −11° C.; *i. e.*, 20° F. below freezing. But 180 atmospheres means 2700′ beneath the surface, where we have a right to expect a normal temperature of 100° to 110° F. (See Sadtler's analyses in Report B; Dewar's experiments in liquefaction, Lond. Ed. and D. Phil. Mag., 1884; Roscoe & Schorlemmer's Organic Chemistry, III, i, 1882, quoting Caillaitet.) Of the other elements, *æthane* and *propane* (which make only 1 per cent to 6 per cent,) *æthane* liquefies under 45 atmospheres at 35° C. (95° F.,) and *propane* under a moderate pressure at normal temperature. Both of them, and small percentages of *olifiant gas* also, probably exist as liquids in the rock.

and the gas condensed to $\frac{1}{100}$ of its volume at the surface.

Then, $\frac{100}{8} \times 100 \times 27,878,400' = 55,756,800,000$ cubic feet of gas in a square mile. Multiply by 2 square miles for the Murraysville gas-belt, and we get, say 110,000,000,000′; enough to supply a 10-million-per-day well thirty years, or thirty wells of that size one year.

But this calculation is based upon data which are ideally high. An average of $\frac{1}{8}$ porosity for 100′ of sandrock is certainly extravagant; $\frac{1}{10}$ would be nearer true. Moreover, 100 atmospheres is the *extreme* pressure at 1400′ depth, and no calculation can be based upon it. On the other hand, the Murraysville area *may* extend (as gas area) much beyond a belt 4 miles long by half a mile wide. But, taking the result as it stands, the yield of each of the thirty wells would steadily decline from 10,000,000′ at the beginning to 0′ at the close of the year, their efficiency at Pittsburgh ceasing much earlier.

The greater force of the Murraysville wells over those in Washington and Butler county may perhaps be explained by the greater thickness of porous rock, confined to a smaller area, the gas therefore reaching the wells with less retardation.

Dr. Chance's calculation of a grand total is based upon a *supposed* proportion of *productive* to *non-productive* o
territory in the Butler-Clarion-Venango region of 150: 1
sq. miles, and an application of this $\frac{1}{10}$ ratio to the
burgh gas region, thus: 2830 sq. m. around Pitt
(within a radius of 30 miles) ÷ 10 = 283 sq. miles
ble gas-rock area. This × 7,000,000,000′ gas =
000,000 per square mile, capable of feeding 5
foot wells one year, or 54 such wells ten ye

Another equally fanciful calculation m
ring belt one mile wide, thirty miles
This would give, say 100 square mile
and 192 ten-million-foot wells, last

Such calculations are not of
underground data, except as
to the community of busine
formation.

No such ring belt exists around Pittsburgh; of that we may be quite sure. The gas areas are evidently small; scattered irregularly; hemmed in by water-areas and oil-areas, and not absolutely stationary, but shifting their positions slowly. This shifting will become comparatively rapid as the stock of gas gets drawn off in the direction of the working wells; and what was at first a gas-field becomes changed to an oil- or water-field; allowing unexploited gas-fields to move forward towards the areas of artificially lowered pressure; but only along the loose sand streaks in each formation.

Such calculations as the above, however imperfectly successful, will be repeated in improved forms as we get fresh facts; the principal point of knowledge being a carefully recorded rate of decline in the gauge pressure at each well. I consider it certain that any accurate knowledge to be got respecting the condition and quantity of the gas underground will be got by—and almost only by—a systematic accumulation of recorded well-pressures. The greatest pains should be taken to get this particular class of facts. To this end, automatic self-registering vacuum-gauges should be lowered to the bottom of every gas well, at regular time intervals, and records of their readings kept. It may not be possible to do this; but the effort should be made at least, at some one test well in each group, in each district. Such a gauge could be made strong and be loaded heavily enough to sink. No one knows yet even the simple fact of the proportionate gas-pressure at the bottom of a 1500′ well and at its mouth. The difference would determine the friction in a tube of that size.

What is true of any one great gas-horizon must be true of other higher or lower horizons, viz: that all calculations made at present fail for want of certain data. I think however, that in the course of the next two years the visible exhaustion of some one area like the Murraysville will enable careful observers to reconstruct their equations and come to very useful conclusions as to the quantities of gas at their disposal; *i. e.*, the probable data to be assigned to the exhaustion of the whole gas region.

The exhaustion of the gas stock underground will of course depend on the amount abstracted. Dr. Chance takes for his calculation *the consumption of coal.*

If the Pittsburgh region replaces 20,000 tons of coal per day with an equivalent (20,000×30,000′) 600,000,000 cubic feet of gas per day, or 219,000,000,000′ per annum, and wastes none extra in the process, it is easy to predict total exhaustion in a very few years. If the whole supply came from the Murraysville wells, it would not last by the first calculation given above, one month; by the second calculation given above, six months. In fact however, it is at present drawn from four gas fields around Pittsburgh; and to these others will probably be added; but I see no good reason for supposing them any more copious than the Murraysville field; nor that so vast a drain could be sustained by them all combined for more than three or four years.

3. Rock-gas composition.

Oil-well-gas is a compound of carbon and hydrogen, or rather a mixture of a good many such compounds:

1. Marsh gas, $C+H^4$, "fire damp," colorless, odorless, not condensable.

2. Aethan, C^2+H^6, colorless, almost ordorless; slightly luminous flame.

3. Propan, C^3+H^8, colorless; condensable to a liquid form at 1° F.

4. Butan, C^4+H^{10}, colorless; liquid below 32° F. (Warren; other authorities say at 63°, and at 68° to 86°.)

5. Pentan, C^5+H^{12}, of at least three varieties, two of which have been found in our petroleum; one, a colorless liquid passing into gas when heated to 99°-103° F., and therefore coming up as gas from wells over 2500 feet deep; the other, a colorless liquid passing into gas at 86° F., and therefore coming up as gas from wells 2000 feet deep.

The remaining compounds in petroleum have too high a boiling point to present themselves in the form of gas at the mouth of any of our wells. They are obtained by distilling petroleum.

6. Hexan, C^6+H^{14}, four varieties, two of which had been

obtained from Pennsylvania oil previous to 1875*: one, a mobile liquid, becoming gas at 144°; the other, at 157° F. These heats are represented by depths of say 5000 feet more or less. But at the well mouth, the excessive cold, due to expansion, would immediately restore these gases to their liquid state.

7. Heptan, C^7+H^{16}, four varieties, two at least recognized in Pennsylvania petroleum by Schorlemmer; one, boiling at 194°; the other, at 209° F., representing depths of 7000 and 8000 feet beneath the surface.

8. Octan, C^8+H^{18}, two varieties, both found in our petroleum; one, boiling at 241° to 246°, the other, at 254° to 257° F.

9. Nonan, C^9+H^{20}, boils at 303° F.

10. Decan, $C^{10}+H^{22}$, boils at 330°+F.

11. Undecan, $C^{11}+H^{24}$, boils at 356°+F.

The solid paraffines of the Ethylene, or Olefine series, are represented in Pennsylvania petroleum by:

Decylene, $C^{10}+H^{20}$, boils at 347° F.

Undecylene, $C^{11}+H^{22}$, boils at 383° F.

Bidecylene, $C^{12}+H^{24}$, boils at 402° F.

The Benzole (aniline dye) series with a formula C^n+H^{2n-6}; the naphthaline (color) series, C^n+H^{2n-12}; the anthracene series, C^nH^{2n-18}; do not seem to be represented.

4. *Rock-gas fuel-value.*

One pound of coal weighs 25 cub. ft. of gas.

One pound of coal has a fuel-value of 7½ cub. ft. of gas.†

1000′ of gas = 1 bushel (76 lbs.) bit. coal.

In 1885, 300 miles of gas mains to the factories and dwellings of and around Pittsburgh furnished heating

---

*See Dr. Sadtler's appendix to Report B, p. 172, from which these facts are quoted.

†This was the *revised judgment* of the Committee of the Engineers' Soc. W. Pa., who reported that a boiler (which did not quite satisfy them as giving the most economical results) which evaporated 9 lbs. water by 1 lb. coal, evaporated 20.81 lbs. water by 1 lb. gas. Allowing 25¼ cubic feet to 1 lb. of gas, we have: (1) 1 lb. gas = 2.255 lbs. coal; and (2) 1 lb. coal = 10.12 cub. ft. gas for evaporating water. But, for the above reason, say 7½. (See description of test in *Scientific American*, supplement No. 520, December 19, 1885.)

power equal to 2,000,000 bush. of coal per month=1,000,000 tons of coal per annum.*

Before the end of 1885 one gas company in Pittsburgh reported 335 miles of pipe of all sizes, displacing the use of about 10,000 tons of coal per day, or 3,650,000 tons per annum, the consumption growing rapidly.†

Probably 5000 men will be dispensed with.‡

The waste at the wells being at first enormous, there was no economy at the works; but of late precautions have been taken to economize the supply.

The gas is odorless, because free from sulphur, etc.

This purity must be taken into account in estimating its value as a fuel. It makes better iron, steel, and glass than can be made with coal gas or coal.§

It makes steam more regularly, because there is no opening or shutting of doors, and no blank spaces left on grate bars for the entrance of cold air. When properly arranged, its flow regulates the steam pressure, leaving the engineman nothing to do but watch the steam gauge.

Boilers last longer, and fewer explosions result from unequal expansion and contraction when cold air strikes hot plates.‖

The *theoretical value* of gas as compared with coals is stated in the report of S. A. Ford, chief chemist of the Edgar Thomson steel works, *210,069,604 heat units in 1000 cubic feet of gas*, weighing 38 lbs. avoirdupois, while the same weight of carbon contains 139,398,896.

*Same, page 33. This is more than one third of the total local consumption of coal in 1884-5.

†W. P. Shinn, Feb., 1886. Mr. Carnegie stated in 1885 that the iron and steel mills of Pittsburgh needed 166,000 bushels of coal per day; that 40,000 had been replaced by gas. Sixty glass works needed 20,000 bushels, mostly now replaced by gas. Outside the city limits the replacement had been about the same.

‡In a steel rail mill, instead of 30 stokers per 8 hours (=90 per day to handle 400 tons of coal) only one man per 8 hours is now needed to watch the water-gauges. (Carnegie.)

§This, of itself, proves that it does not originate in coal measures. But, if it be the decomposition of any kind of animal or vegetable tissue it is hard to explain the lack of odor.

‖A. Carnegie.

Therefore, 1000′ gas = 57.25 lbs. carbon, or
Coke, (at 90 per cent carbon) 62.97 lbs., or
Bituminous coal, 54.4 lbs., or
Anthracite coal, 58.4 lbs.*

The gas thus compared with coal by Mr. Ford was a gas of *average chemical composition.* In point of fact, gas from one well differs from gas from another well; and the gas from one and the same well varies in its chemical composition continually.†

Gas from the same well was found to vary in *Nitrogen* from 23 per cent to 0 per cent; in *Carbonic Acid* from 2 per cent to 0 per cent; in *Oxygen* from 4 per cent to 0.4 per cent, and the *component gases* varied likewise.‡

Six samples taken from one well on the 18th, 25th, 28th,

*Mr. Ford premises that these calculations are purely theoretical, giving a maximum heat which will probably never be fully realized by the best arrangements. In conclusion he says that in these calculations no account is taken of the loss of heat by radiation, &c., the only object being to compare the fuels in respect to their heat units.

†It follows in the case of wells in the same gas basin and gas rock, that if the wells differ each well must vary. Arrange four wells in a square, N., E., S., and W., around a fifth well in the center of the square; then the gas of the center well will come from N., E., S., and W., at varying rates of speed, according to the quality of the rock. It will therefore deliver a varying mixture of N., E., S., and W. gases. Place three other wells E., N., and W. of the first N. well; then the first N. well will behave in like manner; and so on throughout a group. But what are we to think of such a state of things in the gas rock? Has it once been charged with a homogeneous gas, and has the gas been subsequently differentiated? Has it always been charged with one kind of gas here, another there; and are these various kinds of gas now mingling for the first time? If each kind has always been localized does not that fact (if a fact) settle the question of the original production of the gas in the rock itself? Can ascension from below of any but homogeneous gas into the sandrock be conceived? or even if variable gas came to the sandrock from below, must they not have mingled to have produced a homogeneous charge in the rock? Other questions can be asked. The fact of *variable composition* seems to me to be the pivot of the discussion on the origin of gas. It seems, moreover, to bear with great weight on reasoning about porosity, pressure, velocity, and quantity.

‡Wel s deposit interesting minerals. In one case the pipe was nearly choked with soft grayish-white *chloride of calcium.* In another case the first rush of gas threw out crystals of *carbonate of ammonia,* and when this first issuing gas was tested, Mr. Ford found a "considerable amount of that alkali." In about 2 months the gas of this well began first to show *chloride of calcium.* Both these deposits are directly referable to the presence of salt water somewhere in the rock behind the gas.

following analyses :*

	(*a.*)	(*b.*)	(*c.*)	(*d.*)	(*e.*)	(*f.*)
Marsh gas, ...	57.65	75.16	72.18	65.25	60.70	49.58
Hydrogen, ...	9.64	14.45	20.02	26.16	29.03	35.92
Ethylic hydride, ...	5.20	4.80	3.60	5.50	7.92	[illegible]
Olefiant gas, ...	0.80	0.60	0.70	0.80	0.98	0.60
Oxygen, ...	2.10	1.20	1.10	0.80	0.78	0.80
Carbonic oxide, ...	1.00	0.30	1.00	0.80	0.58	0.40
Carbonic acid, ...	0.00	0.30	0.30	0.60	0.00	0.40
Nitrogen, ...	23.41	2.89	0.00	0.00	0.00	0.00

The *heat-units* of these six samples of gas vary accordingly ; thus :

(*a.*) Gas collected October 18, 1884, ... 592,380
(*b.*) Gas collected October 25, 1884, ... 745,591
(*c.*) Gas collected October 28, 1884, ... 728,746
(*d.*) Gas collected October 29, 1884, ... 698,852
(*e.*) Gas collected November 24, 1884, ... 627,170
(*f.*) Gas collected December 4, 1884, ... 745,813

And this variation of the *fuel value* of gas may explain the dissatisfaction with the *pressure* so often telegraphed from the works to the central office in Pittsburgh. When the heat fails, the engineers, puddlers, and glass-makers blame the pipe-supply, when they should blame the chemical composition of the gas.†

An average of the six analyses and heat-units would be as follows :

---

*The figures in the above table are copied from the printed figures in the *Amer. Man. Supplement, April, '86*, and may contain errors. The great quantity of *nitrogen* found in the first sample (Oct. 18th) is very remarkable, and shows a large mingling of air with the gas.

† The analyses of the chemist of the Cambria Iron Company, at Johnstown, exhibit similar variations. But Dr. Chance has suggested a possible serious source of error in our calculations of fuel-value based upon the heat-units of the elements of rock-gas, if we accept without challenge analyses like those of Dr. Sadtler and Mr. Ford, which show what is supposed to be *free hydrogen* ranging in the most remarkable and incomprehensible manner from a minimum of say 10 per cent. to a maximum of say 40 per cent. In gas-analyses "free hydrogen" cannot be separately obtained and its volume or weight directly measured. Its percentage is a calculation, and may be a deception. There is no conclusive proof that hydrogen exists *free* in the well-gas. And it is a very significant fact that when the percentages of marsh gas, hydrogen, and ethylic hydride are added together and recalculated, the variability of the series of analyses, in respect of its fuel value, disappears.

Marsh gas,	67.00	48.0256	627,358
Hydrogen,	22.00	1.9712	67,929
Ethylic hydride,	5.00	6.7200	77,679
Olefiant gas,	1.00	1.2534	14,910
Oxygen,	.80	1.1468	—
Carbonic oxide,	.60	0.7536	1,808
Carbonic acid,	.60	1.2257	—
Nitrogen,	3.00	3.7632	—
(3.761 cub. feet)=(1000 grains=)		64.8585	789,694

in which (x) shows percentages in 100 liters; (y) weights in grammes; (z) heat-units. Consequently, 1000 cubic feet (=265.887 grains=38 lbs.) contain 210,069,604 heat-units. But 38 lbs. *carbon* contains 139,398,896 heat-units. Therefore, 57¼ lbs. carbon=1000 c. f. gas. In like manner 63 lbs. *coke* (90 per cent carbon)=1000 c. f. gas. Therefore, when *coke* is worth $2.50 per net ton *the fuel-value of gas is 8 cents per 1000′*. By similar reasoning on the use of the better qualities of Pittsburgh *coal* (54¼ lb.=1000′ gas), when the coal is at $1.25 per net ton *the fuel-value of gas is 3½ cents per 1000′*.

Coal-gas (*artificially produced*), well purified, has recently had its fuel value determined at 580,000 heat-units per 1000 cubic feet. Hitherto its value has been overstated.†

It is specially noteworthy that the *artificial coal gas* varies in fuel value, just as the *natural gas* varies.‡

* Ford's report to the Edgar Thompson Steel Works, quoted by A. Carnegie.

† Aimé Witz, in Ann. de Chem. et de Physique. (See abstract in Eng. and M. J., N. York, March 6, 1886, p. 167.) He cites Accum's treatise on gas lighting, where 16,000 calories for 1 cub. m. gas is evidently too high. F. Fischer, by a similar method, raised from 32° to 212° F. 2.2 lbs. water with 0.974′ gas. Lefebvre could not do it with less than 1.126′. The greatest available heat in gas furnaces is therefore 3600 cal. per cub. meter. No heat-unit calculation can be got from this method. Dugald Clark has estimated Manchester gas at 5640 and London gas at 5372 cal. (=504,888 and 489,268 foot-pounds per cub. foot gas.) Witz, by Bertholot's explosion method, after many experiments under varying conditions of time, heat, and pressure, got the average of standard French gas as 5200 cal. per cub. m. (=584,000 British units per 1000′.) The generally accepted standard of 6000 is therefore too high.

‡ Gas from the same works varied at different seasons of the year from 4719 to 5425 calories; and comparing coal-gas from different gas-works, the range of variation was found to differ little at the different works. This shows that the variation is an essential element in the manufacture itself, and does not

lb. bituminous coal, (or 41,000′ gas=2240 lbs. coal,) it will be quite safe to adopt a practical *equivalence* of 30,000′ gas to 1 ton coal.

The difference in two volumetric analyses of Grapeville dry gas, made by Mr. Morrell, the chemist of the Cambria Iron Company, in February, 1886, is very striking:—

	Grapeville gas.	
	Feb. 6.	*Feb. 13.*
Marsh gas,	35.06	14.93
Ethyl-hydride,	28.87	39.64
Nitrogen,	27.87	18.69
Hydrogen,	7.06	24.56
Olefiant gas,	0.17	0.96
Oxygen,	0.16	1.22
Carbonic acid,	0.58	trace.
Carbonic oxide,	0.22	trace.
Heat units in 100 litres,	769,766	832,604

Comparing with this the gas of the Siemen's producer at the Cambria Iron Works, the difference in heat value is important:—

Nitrogen,	56.00
Hydrogen,	12.00
Carbonic acid,	4.00
Carbonic oxide,	28.00
Heat units in 100 litres,	121,252

An analysis of the Grapeville gas, from a well half a mile north of Grapeville, in Westmoreland county, the well being 1099′ to top of sand, and 1102′ deep, gave:—

depend upon the management of the works. The purifying process destroys 5 per cent of the fuel value of coal gas. The produce of the last hour of distillation has a lower (not higher) value than the first hour. The value is increased 77 per cent by carburation with gasoline; the gasoline employed becomes rapidly less volatile, and, when reduced to one fourth its volume, has an enriching power of only 34 per cent. 1 gas + 6 air produces complete combustion, leaving no trace of carb. oxide; but excessive dilution causes manifestly imperfect combustion. F. W. Hartley's experiments with 15-candle coal-gas gave 622,000 h. u. per 1000.′ (See Trans. Gas Inst., 1884.)

	Percentage by volume.	*Heat units (100 litres.)*
Marsh gas, CH_4,	35.08	297,549
Ethyl-hydride, C_2H_6,	28.87	447,171
Nitrogen,	27.87	000.000
Hydrogen,	7.05	21,866
Olefiant gas, C_2H_4,	0.17	2,520
Oxygen,	0.16	0.000
Carbonic acid,	0.58	0.000
Carbonic oxide,	0.22	660
	100.00	769,766

It may be well to place on record the current prices of *rock-gas* charged to consumers at Pittsburgh, by the Philadelphia Company, which may be taken as the ruling prices, in April, 1886, as reported in the trade columns of *Eng. & Min. Jour.*, N. Y.:—

Iron and steel:		
Puddling, gross ton,		$1.00
Heating (each heat), gross ton,	$0.40 to	.60
Boilers, per month,	50.00 to	100.00
Total cost gas per ton iron, single heated, gross ton,	1.80 to	2.10
Sheet iron or steel, gross ton,	2.25 to	2.60
Hoop iron or steel, gross ton,	2.25 to	2.60
Open hearth melting, gross ton,		.70
Crucible steel melting, gross ton,		.50
Hammer furnaces, per day,	1.00 to	1.60
Glass:		
Flint, each 10-pot furnace, per month,		160.00
Flint, each large glory-hole, per month,		30.00
Flint, each small glory-hole, per month,	15.00 to	20.00
Flint, each lear, per month,		25.00
Flint, each steam-boiler, per month,	35.00 to	50.00
Average cost gas, about $28 a pot per month.		
Window glass—Average $33.33 a pot per month, blowing furnaces, flattening ovens, sand furnaces and boilers included.		
Green bottle glass, same as window glass.		
Boilers in general works range from $20 to $150 a month.		
Oil stills, per month,	35.00 to	100.00
Brick kilns and drying floors, per M.,		1.00
Fire-brick, per M.,	1.00 to	1.40

Domestic use—This is based on number of square feet heated, the basis being $10 a year for 15 square feet. The charge for heating stoves is $2.50 per month, for open grates, $2.00.

The Philadelphia Company supplied the following in in March:

Boilers,	967
Heating furnaces, large,	587
Heating furnaces, small,	223
Puddling furnaces,	505
Crucible furnaces,	21
Open-hearth furnace, (with running attachments,)	13
Hammer,	58
Nut, bolt, and chain,	60
Glass-melting pots,	623
Glory-holes, lears, ovens, &c.,	378
Oil stills,	31
Brick-kilns,	18
Drying-floors,	23
Dwelling houses, over	4,500

The incrustation of a gas well was found to be *common salt* (chloride of sodium) containing only traces of magnesia and potash (sulphates being absent), practically entirely soluble in water.

Another incrustation from the casing of a well was, on the contrary, essentially *silicate of alumina*:—Sil., 50.70; Al., 41.10; Water, 3.95; with traces of Iron, Manganese, and organic matter.

Shall I bore for gas at my works? is a question so often asked and so seldom answered with intelligence, that a short statement of the principles involved in a correct answer to it will probably be of use to more than one reader of this report.

First of all, there can be no gas stored up *in the oldest rocks*. This at once settles the question in the negative for the whole south-eastern third of the State. To bore for gas in Bucks, Montgomery, Philadelphia, Delaware, Chester, Lancaster, York, or Adams counties would be simply absurd.

Secondly, there can be no gas left underground *where the old rocks have been turned up on edge and overturned, fractured and recemented, faulted and disturbed in a*

found innumerable ways of escape into the atmosphere. This settles the question in the negative for all the counties of the great valley: Northampton, Lehigh, Berks, Lebanon, Dauphin, Cumberland, and Franklin, as any one can see by looking at the present condition of their limestone, slate and sandstone formations.

Thirdly, there is not the least chance that any gas is left underground *in the greatly folded, faulted, crushed, and hardened formations of the middle belt of the State:* Carbon, Schuylkill, Lehigh, Luzerne, Columbia, Montour, Northumberland, Union, Snyder, Lycoming, Perry, Juniata, Mifflin, Centre, Clinton, Huntingdon, Blair, Bedford, and Fulton counties. Where the oil- and gas-rocks rise to the surface in these counties, as they do in a thousand places, they show that all their oil and gas has escaped long ago.

Fourthly, *where the rock formations lie pretty flat and have remained nearly undisturbed over extensive areas,*—as in Wayne and Susquehanna, parts of Pike and Lackawanna, Wyoming, Bradford, Tioga, Potter, and all the counties west of the Allegheny mountain,—there is always *a chance of finding gas* (if not oil) at some depth beneath the surface determined by the particular formation which appears at the surface; but as yet we have no satisfactory evidence of the existence of quantities of rock-gas in any of these counties east of Potter.

Fifthly, wherever the bituminous coal-beds have been changed into anthracite or semi-bituminous coal, it is reasonable to suppose that the same agency which produced the change, whatever it was, must have acted upon the whole column of formations including any possible gas-rock at any depth.

Sixthly, wherever rock-oil has been found, there and in the surrounding region rock-gas is sure to exist.

*Report of the Progress of the Geodetic Triangulation of Pennsylvania.**

By MANSFIELD MERRIMAN, *Acting Assistant U.S. Coast and Geodetic Survey.*

It is the object of this article to give an account of the triangulation executed in Pennsylvania during the past eleven years by the United States Coast and Geodetic Survey. The subject will be divided into four parts. First, a statement concerning the nature of the triangulation and the use that can be made of it; second, a brief account of the methods employed; third, a record of the yearly progress of the work, and fourth, a statement of the principal geographical positions thus far determined.

1. *The Nature of a Geodetic Triangulation.*

The operation of triangulating consists in determining, by means of triangles, the positions of points on the surface of the earth, so that they may be laid down on paper in their proper relative locations and serve as a basis for the construction of an accurate map. If the area embraced in the work be large, the form and size of the earth must be taken into account by means of the science of geodesy, and hence the triangulation is called geodetic.

When a land surveyor determines the area of a field by the old method of compass and chain, he measures the length and the magnetic bearing of each of its sides. From these measurements the coördinates of each corner of the field with respect to an assumed origin and axes are easily computed. One of these coördinates is the distance of the point east or west from the assumed meridian; another is the distance of the point north or south of the corner taken as the origin. These two coördinates—sometimes called longitude and latitude—locate the position of the point and enable it to be plotted in its proper place relative to the

* Written for this report by authority of the Superintendent of the U. S. Coast and Geodetic Survey.

others. In geodetic work points are located in a similar manner by means of their latitudes and longitudes. The word latitude, however, is used in its geographical sense as meaning the distance from the equator expressed in degrees, minutes, and seconds of arc, and the word longitude denotes the distance, similarly expressed, from an assumed meridian. The meridian used by the Coast and Geodetic Survey is that of Greenwich. Of course all points in this country are in north latitude and in west longitude.

The question of constructing an accurate map of a given area may be said to reduce to the determination of the latitudes and longitudes of a sufficient number of points. For instance, if the latitude and longitude of each street corner in a town were known with precision, it would be easy to make a map showing the streets by simply plotting each corner by means of those coördinates, and then drawing the proper lines to connect the points. As, however, there is no cheap and accurate method of determining the latitudes and longitudes in such a case, other methods must be used for locating the points so that they fall upon the map in their proper relative positions.

It is one of the objects of the triangulation of Pennsylvania to determine the latitude and longitude of each of its stations. A triangulation, in fact, may be defined as a cheap method of determining the latitudes and longitudes of points. Incidental to this, and yet important for the prosecution of surveys, is the determination of the lengths of the sides of the triangles and of the angles which those sides make with the true meridian.

If the latitude and longitude of a point be determined by means of astronomical observations and computations, its position upon the earth's spheroid is known. Now, if the latitude and longitude of another point in that neighborhood be required, the cheapest method is not to take a second set of astronomical observations, but to determine the distance between the two points and the angle which the line makes with the meridian, and then to compute the difference of latitude and longitude. For example, in Fig. 1 let A be a point whose geographical position has been astro-

tronomically determined, and let B be a second point to the south-westward, whose position is required. Let A M be a meridian drawn through A. Now, if the distance A B and the angle B A M be measured, the distances A M and B M may be computed by plane trigonometry if the line A B is short, or by the rules of geodesy if the length of A B is sufficient to require the curvature of the earth to be considered. These distances A M and B M are then converted into seconds of arc, and the latitude of B is equal to that of A minus the number of seconds in A M, while the longitude of B is equal to that of A plus the number of seconds in B M.

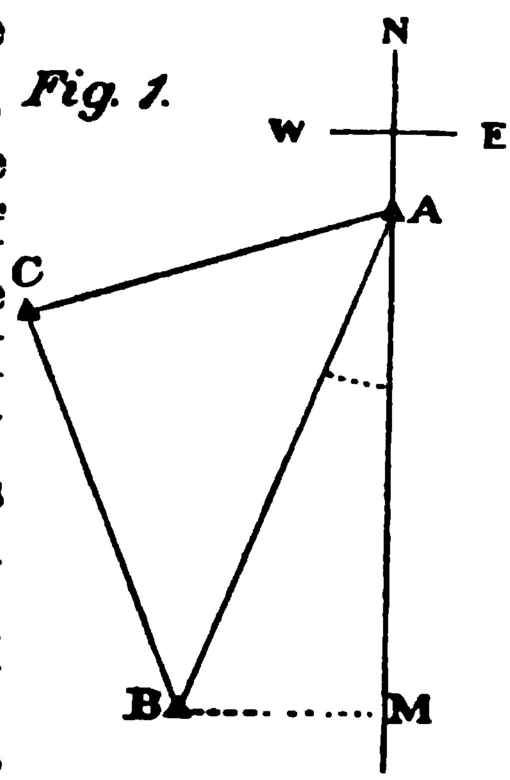


Fig. 1.

If the line A B be long, it will seldom be possible to find its length by direct chaining, but one or more triangles will be necessary. The simplest case is that when a third point C can be found, which is intervisible with A and B, and so located that the distance A C can be directly measured by a chain, or by rods, or by a special base apparatus, as the precision of the work may demand. Then by measuring also the two angles B A C and B C A, we have the complete data for computing, by the rules of trigonometry, the required distance A B. More usually, however, the base line to be directly measured is situated at some distance from the point A, as shown at G H in Fig. 2.

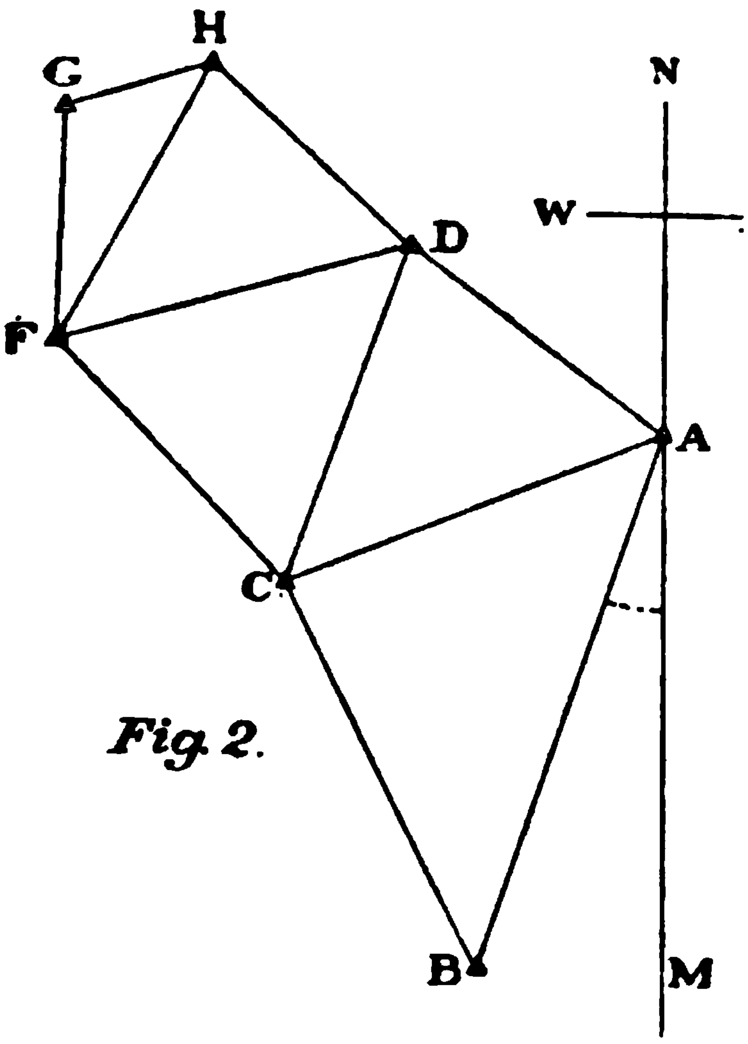


Fig. 2.

Here the side H F is computed from the measured base G H and the angles F H G and H G F. Then from the known length of H F, and the angles of the triangle H D F, the side D F is found, and thus the computation is carried on

until the required distance A B is found. By extending the computations a step further it is now evident that the latitude and longitude of each of the stations C, D, F, G, and H may be also found; for, since the angle C A M is known, C may be located in the same manner as B, and from C the point F is located, and so on in order.

It will be seen, from the above explanation, that a geodetic triangulation includes five distinct kinds of field operations; first, the astronomical determination of the latitude of a station; second, the astronomical determination of the longitude of a station; third, the astronomical determination of the azimuth (or angle made with the true meridian) of one of the sides; fourth, the measurement of a base, and fifth, the measurement of horizontal angles. Practically, however, the greater part of the field work of a triangulation consists in the observation of angles, since it is found that the latitudes and longitudes of points two or three hundred miles distant from an astronomical station can be computed through the triangles with the necessary precision and with a less expense than by other methods.

Suppose now that a triangulation, like the one shown in Fig. 2, has been completed. What use can be made of it? The two coördinates—latitude and longitude—are known for each of the stations. At each station the azimuths (or true bearings) of all the lines radiating from that station are known. The lengths of all the sides of the triangles are known. How can these be used to construct an accurate map of the country?

In the first place, it may be observed that the triangulation furnishes the exact geographical positions of a number of points, so that these may be plotted in their proper places with respect to a system of parallels of latitude and meridians of longitude. Starting at one of the stations—for instance at C—a surveyor may at once determine the true meridian, since the true bearings of each of the lines C A, C D, etc., are known. Then he may make a local survey of the country around C, locating the roads, streams, houses, State lines, county lines, etc., with reference to that true

may be made for that vicinity. These topographical surveys may now be plotted on the map, and each will be in its proper position with reference to the other. If the survey made from F be extended to meet that made from C, there is afforded a check upon the accuracy of the local surveys. Hence the inaccuracies of the topographical work cannot spread and increase, for a constant system of independent checks is obtained wherever a connection can be made with the triangulation. The triangulation forms a net-work, or rather a frame-work, upon which everything else in the map is hung. This large frame-work is constructed with care and accuracy, and all surveys connected with it are properly connected with each other through it.

In the second place, it is maintained that the cost of an extended topographical survey is a minimum when based upon a geodetic triangulation. Each side of the triangulation furnishes a base line, whose length and azimuth are known. The great value of an accurately determined base line for the prosecution of topographical work will be evident to every surveyor. From it other points may be located and other lines of reference obtained. The true bearing, or azimuth, of every line of the survey is at once determined without the expense of astronomical observations. By the help of the three point problem, stations for the use of plane table or stadia (telemeter) parties may be quickly located. The constant system of checks renders the accumulation of large errors impossible, and hence less revision of the field work is required. Thus the effect of a triangulation is to lessen the cost of topographical surveys and maps.

Another use of the triangulation that will be ultimately made is that of furnishing reference points for the precise description of the boundary lines of land properties. No system for this purpose has yet been adopted in Pennsylvania, and as a consequence the majority of land records are so defective that the retracing of old lines from the recorded descriptions is often impossible, and almost always attended with trouble and expense. Ultimately, when the

secondary and tertiary triangulations become extended, so that one or more stations are located in every township, the monuments which mark these stations will enable a system to be formulated whereby the boundaries of every farm may be accurately described. Or, in other words, from these monuments the latitude and longitude of each corner of the farm may be computed and recorded; to recover a lost corner it will then only be necessary to run the proper lines from the nearest monument, or nearest known corner, so as to determine the point whose geographical position is given.

2. *The Methods of Geodetic Triangulation.*

Two classes of triangulation are usually recognized in geodetic work; the primary series, which connects directly with the bases and which employs the longest possible lines; and the secondary series, which determines points within the larger triangles. To this is often added a tertiary series which locates stations for the special use of plane table and stadia (telemeter) parties. On the U. S. Coast and Geodetic Survey it is required that in the primary series the probable error of a determined angle should not exceed 0″.3, and that the limit of error in closing a triangle should not exceed 3″, while for the secondary series the corresponding values are 0″.7 and 6″ respectively.

The first field operation is that of reconnaissance, which decides upon the locality of each of the stations. These are to be so selected as to secure the best system of triangles, quadrilaterals, or hexagons, to cover the given area so as to satisfy the prescribed conditions of accuracy and minimum cost, both in the execution of the triangulation and in the subsequent use that is to be made of it. For the stations of the primary series usually the highest elevations are selected, and accordingly the longest possible lines obtained consistent with the formation of well proportioned figures. The intervisibility of adjacent stations must of course be insured, and if possible approximate values of the principal angles be determined. For a full account of the conditions required to be observed in reconnaissance work, see

151—155.

The measurement of a base line is an operation which requires the most precise apparatus and careful field work in order that its length may be accurately determined. As a primary base line is only 5 or 10 miles in length, while the sides of the primary triangles usually exceed 20, and are sometimes more than 50 miles long, it is evident that any error in the measurement of the base will be multiplied in the longer lines, and accordingly the greatest precision in the linear measurement is demanded. The probable error, or uncertainty, in the length of the measured bases on the *eastern* coast of the United States is about $\frac{1}{250000}$th part of the length, although the lower value of about $\frac{1}{500000}$ was attained in the cases of the Massachusetts and the Epping base. The former of these fractions is equivalent to an uncertainty of a quarter of an inch in a statute mile, and the latter to one eighth of an inch per mile. Concerning base line measurements, the following articles in the Reports of the Coast and Geodetic Survey are among others referred to: Report of 1854, pp. 103–108; Report of 1864, pp. 120–144; Report of 1873, pp. 123–136; Report of 1880, pp. 341–344; Report of 1882, pp. 107–149; Report of 1883, pp. 273–288.

The determination of the astronomical latitude of a station is generally effected by measuring with a zenith telescope the differences of the zenith distances of several pairs of stars. The longitude of a station is found by comparing by means of the electric telegraph the local time of the meridian of the station with that of some astronomical observatory whose longitude is known. The azimuth of one of the lines of the triangulation, or the angle which it makes with the true meridian at one of the stations, is determined by observations on circumpolar stars. For a full account of the methods of determining latitude, longitude, and azimuth, reference is made to the papers in the Report of the Coast and Geodetic Survey for 1880, pp. 201–286.

The field work of the triangulation in Pennsylvania has thus far consisted only of reconnaissance, and of the

measurement of horizontal angles, the latitudes, longitudes, azimuths, and distances being determined by computations from the connection with the main triangulation of the coast, which, in its turn, is connected with the base lines and astronomical stations. The nearest bases are the Fire Island base, on the southern coast of Long Island, and the Kent Island base, on the eastern shore of Chesapeake bay opposite Annapolis. The nearest station where azimuth has been observed is Principio, in the north-eastern part of Maryland, and the nearest latitude and longitude stations are also in that State.

The measurement of horizontal angles hence constitutes the principal part of the field work of a triangulation. This, although theoretically of a simple nature, is in practice attended with some difficulty on account of the distance of the signals and the necessity of securing a high degree of precision in the observations. The wooded character of the summits upon which the stations are located in this State has rendered it usually necessary to erect towers varying in height from 15 to 60 feet. A single tripod is first constructed to support the theodolite, and around this an independent scaffold is built, so that the motions of the observer may not be communicated to the instrument. For signals to be observed upon at the surrounding stations, targets and heliotropes have been employed, the former being used for lines less than about 20 miles in length, and the latter for longer lines. The heliotrope is an instrument by means of which the rays of the sun are reflected from a small mirror so as to strike the observer's station, and which are seen by him in the form of a small bright star or spot of light; for long lines the heliotrope signal is almost indispensable, since targets can only be seen under the most favorable atmospheric conditions.

The instrument used for the measurement of the horizontal angles in this State is a Gambey repeating theodolite with a limb ten inches in diameter, and reading by two verniers to three seconds. The angles have been read in sets of four or six repetitions each, the average total number of single measures for each independent angle being

usually from 90 to 120. In each set one half of the measures are made with the telescope in the direct position, and the other half with it in the revsrse position, in order to eliminate any error in the level of its horizontal axis. Both verniers are read in order to eliminate any error of eccentricity in the graduated plate. Usually, also, the sets are taken alternately from left to right and from right to left, in order to balance any errors arising from the use of the clamps or from a motion of the tripod. The different sets are taken upon different parts of the circle to eliminate any errors in the graduation of the limb. Lastly, the observations are continued over several days in order that the signals may be seen under different atmospheric conditions. The following is an example of four sets taken at Bake Oven station on August 26, 1885:

Station observed.	Time.	No. of Reps.	Reading.				Angle.
				A	B	Mean	
Smith's Gap, ...	3:45		0° 00′	00″	12″	06″.0	
		4					98° 36′ 58″.1
Knob, ...	4:02		34 27	54	63	58 .5	
		4					98 36 55 .5
Smith's Gap, ...	4:06		0 00	12	21	16 .5	
Smith's Gap, ...	4:33		50 29	33	48	40 .5	
		4					98 36 62 .6
Knob, ...	4:37		84 57	45	57	51 .0	
		4					98 36 60 .4
Smith's Gap, ...	4:40		50 29	42	57	49 .5	

The mean of all the values thus determined for the different sets constitutes the observed value of the angle. Usually the observations are extended to include other angles than the simple independent ones, and, in such cases, an adjustment of the observed values is made by the method of least squares. For instance, the station Bear's Head was occupied in July, 1885, and the five primary stations, Penobscot, Knob, Bake Oven, Port Clinton, and White Horse, were observed upon. These five lines include four simple, independent angles, but the angles observed numbered ten, being all the angles resulting from the combination of the lines

two by two. The following shows the observed and adjusted values of these ten angles:

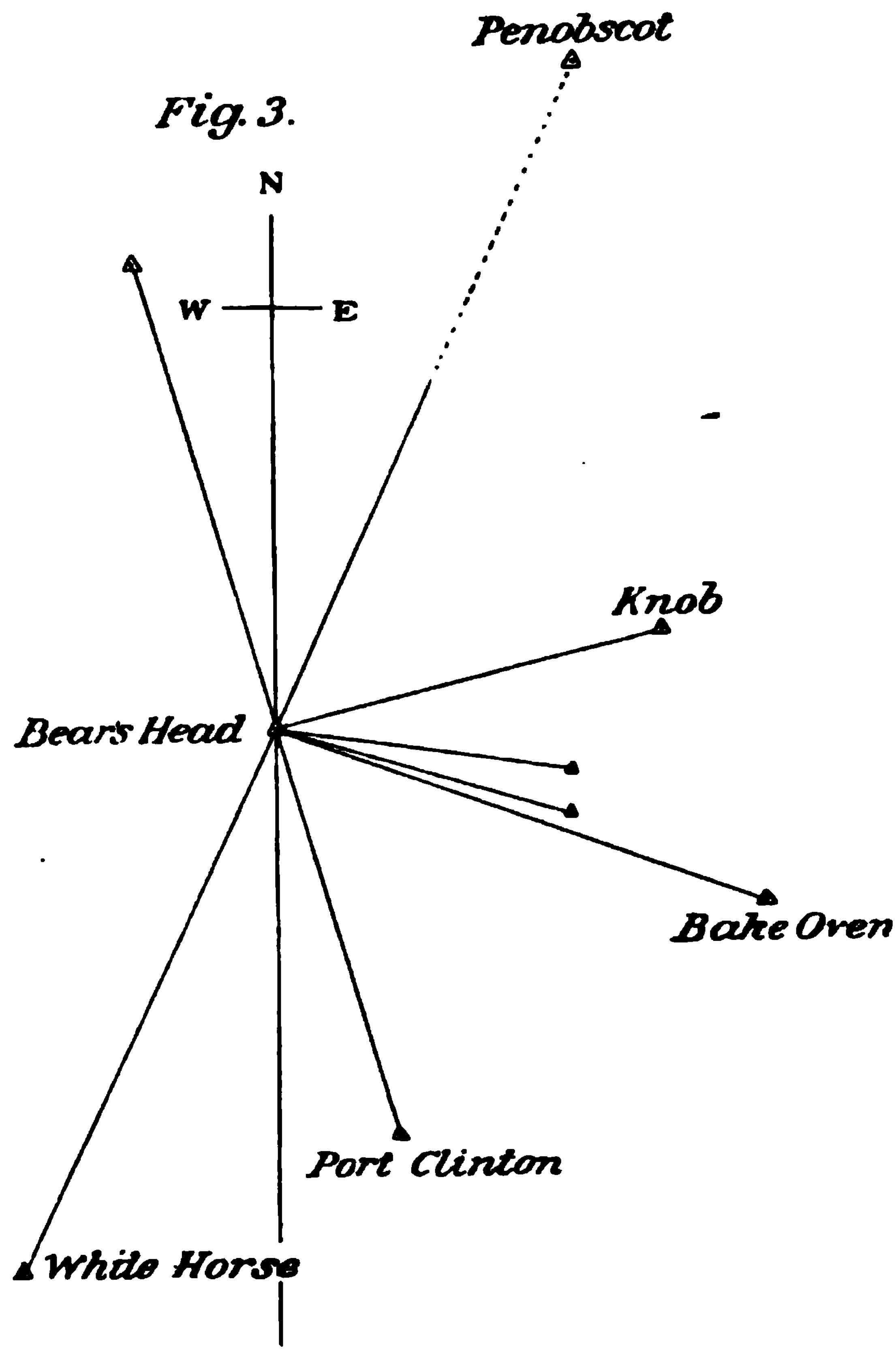


Fig. 3.

Angle at Bear's Head.	No. of reps.	Observed value.	Adjusted.
White Horse—Port Clinton, . . .	48	41° 15′ 39.97″	40.38″
White Horse—Bake Oven, ...	40	94 47 12.71	14.02
White Horse—Knob, ...	48	129 19 47.57	47.09
White Horse—Penobscot, ...	40	180 39 48.43	47.24
Port Clinton—Bake Oven, ...	48	53 31 34.27	33.69
Port Clinton—Knob, ...	48	88 04 05.75	06.76
Port Clinton--Penobscot, ...	48	139 24 06.97	06.91
Bake Oven—Knob, ...	48	34 32 33.16	33.07
Bake Oven—Penobscot, ...	40	85 52 32.39	33.22
Knob—Penobscot, ...	48	51 19 59.71	60.15

average of 114 for each independent single angle. The work at this station began on July 20 and was finished on July 30, but the weather only permitted observations on eight days, and on five of these measurements could not be made until the afternoon.

A full account of the method of marking the stations, constructing the towers and signals, and taking the angle observations may be consulted in the Report of the Coast and Geodetic Survey for 1882, pp. 151–197. This paper also explains the methods of computing the triangle sides and finding the spherical excesses of the triangles.

On account of the curvature of the earth, the horizontal limb of the theodolite is at each station parallel to a tangent plane to the spheroidal surface, and accordingly the sum of the three measured angles of a triangle should be greater than 180°. The spherical excess of the triangle added to 180° gives the quantity which the sum of three measured angles should equal, and their difference is the error in closing the triangle. Having found these errors, a further adjustment is made in order to obtain the corrected spherical angles of the triangle. The following gives the angles and the error of closure in each of the four triangles shown in Fig. 4, all the angles of which were measured during the season of 1885:

Pimple Hill, . .	49°	04′	50.18″	Pimple Hill, . .	29°	58′	51.60″
Smith's Gap, . .	90	21	25.58	Knob, ...	91	57	51.54
Bake Oven, . .	40	33	46.91	Bake Oven, . .	58	03	18.14
Sum, ...	180	00	02.57	Sum, ...	180	00	01.28
180°+excess, . .	180	00	01.66	180°+excess, .	180	00	01.43
Error, ...			+0.91	Error, ...			—0.15
Knob, ...	50	37	17.20	Knob, ...	41	20	34.34
Bake Oven, . .	98	37	05.05	Pimple Hill, . .	79	03	41.73
Smith's Gap, . .	30	45	41.35	Smith's Gap, . .	59	35	44.18
Sum, ...	180	00	03.60	Sum, ...	180	00	00.25
180°+excess, . .	180	00	1.26	180°+excess, .	180	00	01.83
Error, ...			+2.34	Error, ...			—1.58

After using these errors of closure to adjust the spherical angles, the plane angles of the triangles are found and the triangl

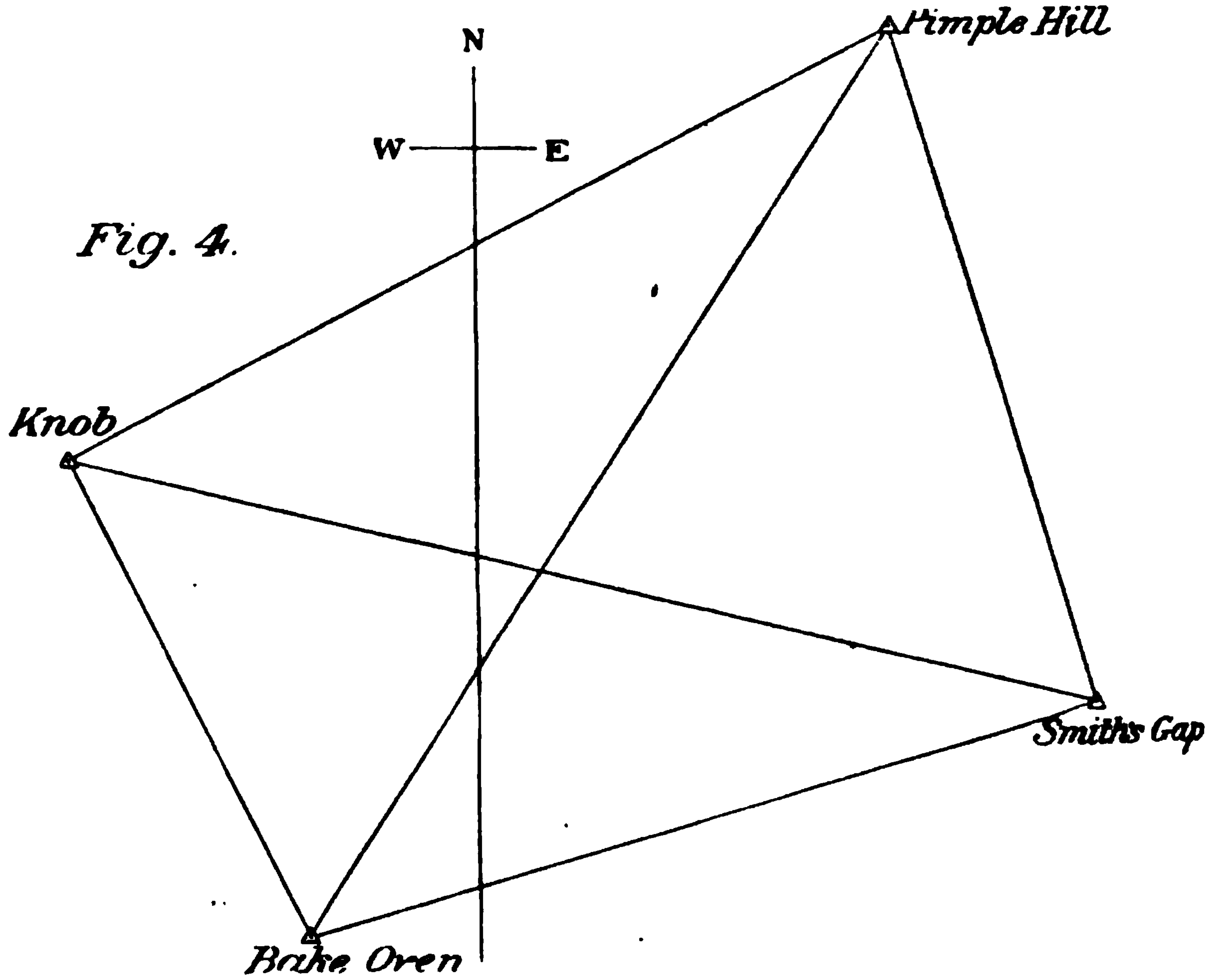


Fig. 4.

longitudes, and azimuths are computed by the methods explained in the Report of the Coast and Geodetic Survey for 1884, pp. 323–375.*

---

*The mean error (m) of an adjusted angle is a quantity which has been advantageously used for comparison of the accuracy of various triangulations, and it will be seen that for the best executed work this measure does not exceed 1″.

Of course it does not follow that all work should possess this accuracy; what is required is a proper degree of accuracy depending upon the object for which the triangulation was undertaken and the means and time it was intended to devote to it. This remark is made in order that no unfair criticism may arise in the mind of the reader in looking over the following collection of some resulting mean errors:

U. S. Coast and Geodetic Survey, Yolo-base figure, Cal., by G. Davidson, 1876 — 1884,	$m = \pm 0.51''$
Survey of Hanover, by Gauss,	0.59″
Survey of Prussia, by Morozowiez, since 1867,	0.62″
Survey of Denmark, by Andrae,	0.71″
Coast Survey of Prussia, by Bessel & Bayer, in 1838,	0.72″
U. S. C. & G. Survey connection of Lakes Champlain and Ontario by secondary triangulation, by C. O. Boutelle,	0.95″
Survey of Penna. by the U. S. C. & G. Survey, so-called Horse-shoe secondary triangulation, by L. M. Haupt and M. Merriman, 1875 to 1882,	1.75″
Ordnance Survey of Great Britain, 1784 to 1858,	2.21″

3. *Progress of the Triangulation in Pennsylvania.*

During the past twelve years, Congress has made a yearly appropriation "for furnishing points for State Surveys," by the extension of the triangulation of the U. S. Coast and Geodetic Survey. The annual appropriation during the past few years has been $16,000, which has been applied in a number of States, the average proportion for Pennsylvania being, previous to 1885, less than one tenth of this sum. This amount has only been sufficient to keep a single party in the field for two or three months of the year, and accordingly the progress of the work has been slow. The following brief statement of the yearly progress is derived from the annual reports of the Coast and Geodetic Survey, except that of the season of 1885, which is furnished by authority of the Superintendent.

In the spring of 1875 the Governor of Pennsylvania, at the instance of the State Geologist, Prof. J. P. Lesley, requested the superintendent of the Coast and Geodetic Survey to extend the triangulation of the coast so as to determine points for correcting the State map. Prof. L. M. Haupt, having been appointed Acting Assistant U. S. Coast and Geodetic Survey, and instructed to execute the work, took the field on July 1, and spent the summer in reconnaissance. Beginning at the eastern end of the Lehigh Valley, and giving attention to the means for joining with known points of the primary triangulation in New Jersey, the stations Smith's Gap and Bake Oven, on the Blue mountain, were first selected. Other stations to the southward, on the Durham and Reading hills, were later chosen, so that, by the close of the season, an acceptable scheme of triangulation had been laid out, extending from the mouth of the Lehigh to points westward of the Schuylkill. During the same season Assistant G. A. Fairfield identified the station marks at Principio, in Maryland, and at Meeting-house hill, in Delaware, which had been established about the year 1840, and made a reconnaissance north-west into Chester county to begin a series of triangles to connect with those of Prof. Haupt.

In the season of 1876 the reconnaissance was continued

and the triangulation work proper begun, six tripods being erected and four stations occupied for the measurement of angles.

During 1877 there were [no funds available for the field work, but in 1878 the party of Prof. Haupt was in the field from the first of June to the middle of October. Four tripods were erected and five stations occupied for the measurement of horizontal angles. Two of these stations were Principio and Meeting-house, and thus a connection was effected with the primary triangulation of the coast, so that, at the close of the season, the geographical positions of the stations Londonderry and Rawlinsville were known.

In the season of 1879 four stations were occupied by Prof. Haupt, and at its close the geographical positions of Beartown, Womelsdorf, and Blackspot stations were computed.

During the season of 1880 six stations were occupied, and two new stations selected and observed upon. At the close of this season Prof. Haupt resigned his charge of the work, and Prof. Merriman was appointed Acting Assistant in the U. S. Coast and Geodetic Survey to continue the triangulation.

In the season of 1881 the triangulation was continued by the occupation of two stations.

In the season of 1882 four stations were occupied, and three new stations definitely located and marked. The measurements made this season closed the connection of a horse-shoe chain of triangles between the primary line, Principio–Meeting-house, near the northern boundary of Delaware, and the line Newtown–Mt. Rose, a few miles north of Trenton, N. J. This chain is shown in the page plate. The two lines just mentioned are a part of the primary coast triangulation whose lengths and positions had been previously determined. In order to show the precision of geodetic work, the following results deduced by the Computing Division of the Coast and Geodetic Survey are here stated:

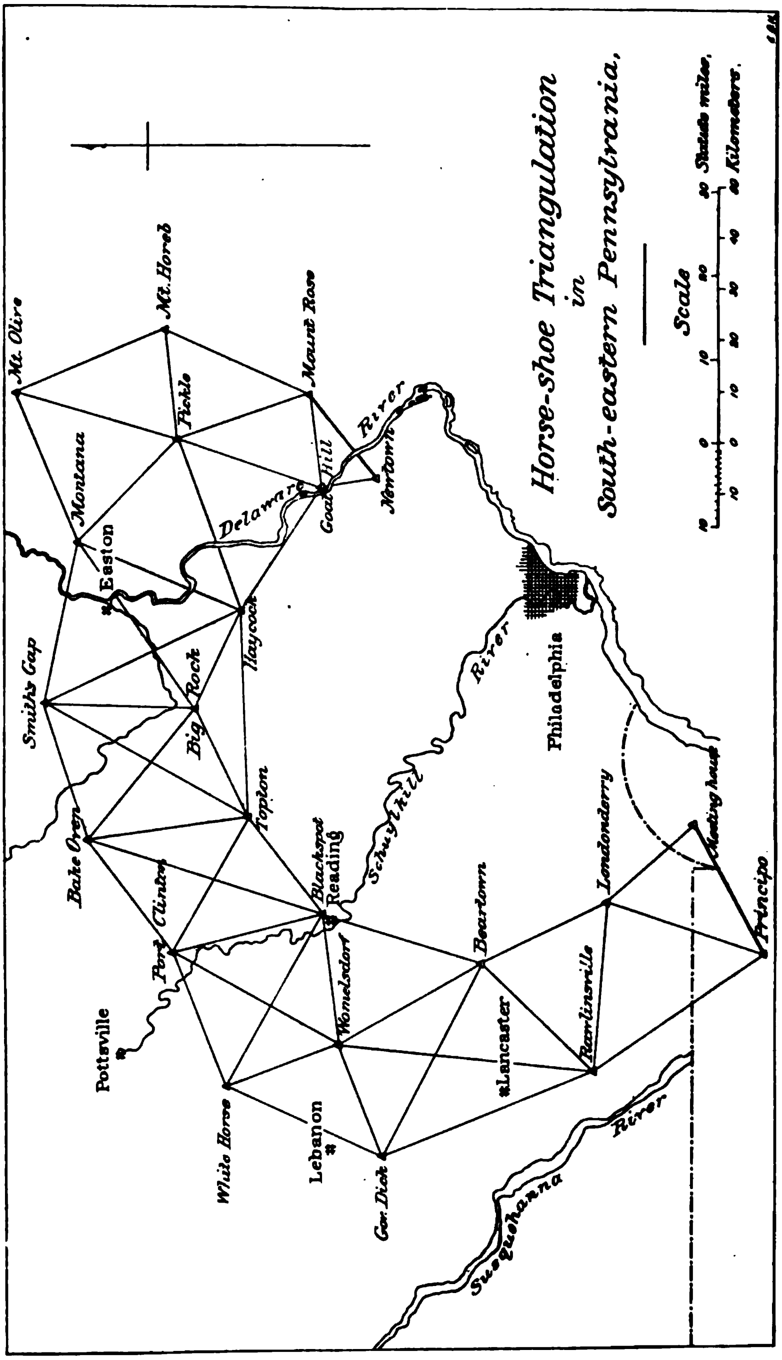
Starting from the fixed line Principio–Meeting-house, the geographical positions were computed throughout the horseshoe chain, and, on arriving at the line Newtown–Mt. Rose,

Newtown to Mt. Rose was found to be 21,
while the same from the coast triangulation
meters, the discrepancy being 3 centimeters.
of the direction Newtown to Mt. Rose was fc
10′ 26.4″, while the same from the coast tri
232° 19′ 10.5″, the discrepancy being 6.9″; t
Newtown was found to be 40° 15′ 03.308″, w
for the coast triangulation was 40° 15′ 03.411′
ancy being 0.103″; and the longitude of Newt
to be 74° 55′ 13.987″, while the same for the
lation was 74° 55′ 13.927″, the discrepancy
The agreement is hence very satisfactory, it
ered that the distance between the two fixed
bases is nearly 150 miles when measured al
of the horse-shoe chain.

In the season of 1883 the triangulation was
the occupation of the stations Gov. Dick, Ro
Winterstown, the two latter being westward c
hanna river. Towers varying in height from
were required at these stations, and also at D
pit Rock, and Swatara Gap, the other point
observed upon.

During the season of 1884 the station Swat
occupied and the horizontal angles measured.
stations were selected and marked, and tripod
them. A reconnaissance was also begun to co
tions on the Blue mountain near the seventy
ian with those in the State of New York. Th
Penobscot Knob, five miles south of Wilke
definitely selected as the place for one of the
horizontal sketches were taken there and at oth
the purpose of laying out a scheme of triangu.

For the season of 1885 a larger sum than u
propriated for the Pennsylvania work in ord
the triangulation more rapidly to meet the
Second Geological Survey. Acting Assistant M
instructed to continue the triangulation northw
anthracite coal regions, Assistant O. H. Tittma


Horse-shoe Triangulation
in
South-eastern Pennsylvania.
Scale
Statute miles.
Kilometers.
Mt. Horeb
Mount Rose
Pickle
Montana
Goat Hill
Newtown
Delaware River
Easton
Haycock
Smith's Gap
Big Rock
Topton
Bake Oven
Port Clinton
Blackspot
Reading
Schuylkill River
Philadelphia
Womelsdorf
Bearltown
Londonderry
Rawlinsville
Lancaster
Pottsville
White Horse
Lebanon
Gov. Dick
Susquehanna River

the reconnaissance between the seventy-fifth and seventy-seventh meridians northward to the New York State line, and Acting Assistant Barnard to continue the work westward of the Susquehanna river.

The party of Prof. Merriman occupied in succession the stations Knob, Bear's Head, Pimple Hill, Smith's Gap, Bake Oven, and Port Clinton. Five new stations were marked, four towers erected, and 30 primary and 23 secondary directions observed. This work has enabled the geographical positions of Knob, Bear's Head, Pimple Hill, Penobscot, and Panther, to be computed, as also the positions of 7 secondary points. The field work of this party began June 23 and closed September 16.

The party of Assistant Tittmann extended the reconnaissance northward across the northern anthracite coal field to the New York State line. Angles were measured with a small theodolite at the stations Panther, Penobscot, Shickshinny, Bald, Moosic, Salem, and Elk, with sufficient accuracy to enable geographical positions to be determined approximately, and permit the collocation of local maps on a general one. Nine secondary stations were determined in the northern anthracite coal field. The field work of this party began June 23 and closed October 24.

The party of Prof. Barnard was engaged in reconnoitering and the erection of towers. He occupied, for the measure of horizontal angles, the station Dauphin, unfavorable weather preventing the occupation of other stations.

The accompanying map shows the present condition of the geodetic survey of the State. The lines which are drawn broken denote reconnaissance only, while the full lines denote that the angles have been measured and the triangulation proper completed.

The primary coast triangulation connecting the stations Principio, Meeting-house, Lippincott, Yard, etc., is seen near the south-eastern part of the State, and resting upon it is seen the horse-shoe chain previously described. Westward of the Susquehanna the reconnaissance ex-

tends to the foot of the Alleghenies, and in the south-western part of the State a scheme of reconnaissance is indicated, extending from the Maryland triangulation westward over the mountains. In the north-western corner of the State is shown the triangulation of the Lake Survey. North of the State line, near longitudes 76° and 77°, are shown triangles of the New York State Survey, five of whose stations fall south of the boundary. Connecting these stations with the triangulation near latitude 41°, is seen the reconnaissance executed during the season of 1885 by Assistant O. H. Tittmann. The scale of the map is 1 : 1,000,000, or 1 inch to about 15¾ miles.

4. Geographical Positions and Results.

The latitude and longitude of a station determine its position on the earth's spheroid. In addition to these it is always important to know the distance and direction from the station to each of the neighboring ones, in order to be able to extend the triangulation or use it for local surveys. The complete statement of a geographical position, hence, includes distance, azimuth, latitude and longitude.

The unit of distance employed by the Coast and Geodetic Survey is the meter. The following constants are adopted, from the latest comparisons, to convert meters into feet and miles when necessary:

$$\text{Meters} \times 3.280869 = \text{Feet.}$$
$$\text{Meters} \times 0.000621377 = \text{Miles.}$$

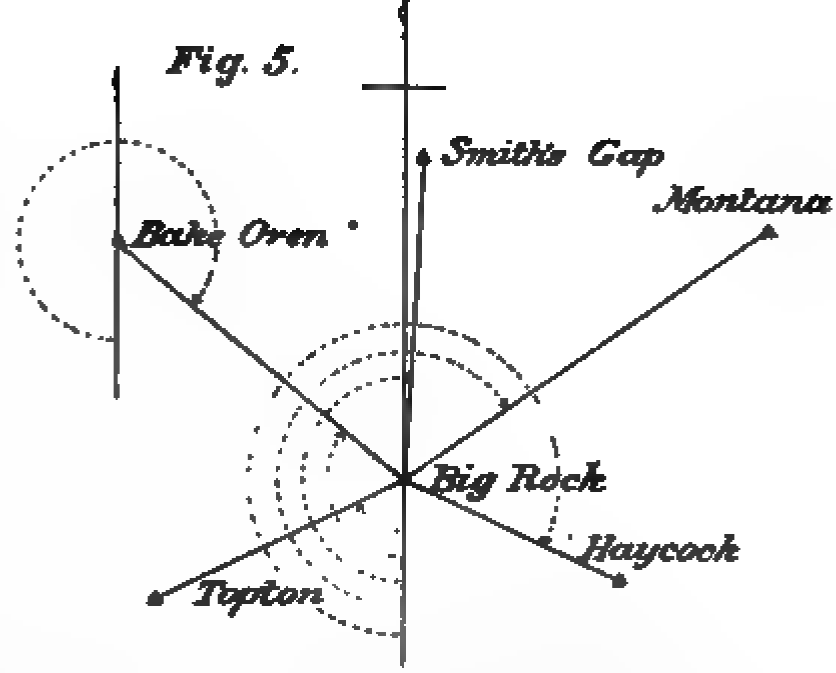
If the logarithm of the distance in meters be known, the conversion may be made as follows:

$$\text{Log meters} + 0.5159889 = \text{Log feet.}$$
$$\text{Log meters} + 6.7933550 = \text{Log miles.}$$

The azimuth of a line is an angle which denotes the direction which that line makes with the true meridian. This angle is always measured at one end of the line with respect to a true meridian passing through that end. On the Coast and Geodetic Survey azimuths are reckoned from the south around through west, north, and east, from 0° to 360°, so

has the azimuth 0°, west 90°, north 180° and east 270°. Hence, the true bearing of a line is at once known when its azimuth has been determined, azimuth and true bearing being, indeed, but different formal statements of the

Fig. 5.



same thing. For example, at the station Big Rock, the following are the azimuths and true bearings to the five stations shown in Fig. 5. It will be seen from the figure

At Big Rock.	Azimuth.	True bearing.
To Topton, ...	64° 54′ 36.61″	S. 64° 54′ 36.61″ W.
To Bake Oven, ...	129 13 35.82	N. 50 46 24.18 W.
To Smith's Gap, ...	182 33 18.74	N. 2 33 18.74 [illegible]
To Montana, ...	235 05 46.52	N. 55 05 46.52 E.
To Haycock, ...	294 32 22.86	S. 65 27 37.14 E.

that the azimuths likewise give all the angles between the stations at the point Big Rock. For instance, the angle Bake Oven–Big Rock–Topton is 64° 18′ 59.01″, the difference of the azimuths Big Rock–Bake Oven and Big Rock–Topton.

On account of the spheroidal shape of the earth the meridians are not parallel but converge toward the poles. If the surface of the earth were plane the azimuth of the direction Bake Oven to Big Rock (in Fig. 5) would be exactly 180° greater than that of the direction Big Rock to Bake Oven, but actually we have the azimuths:

Big Rock to Bake Oven, 129° 13′ 35.82.″

Bake Oven to Big Rock, 309° 02′ 01.43.″

In this particular case, then, the convergence of the meridians has caused the true bearing of the line taken at Big

Rock to be 11′ 34.39″ greater than the true bearing of the same line taken at Bake Oven.

Owing to the spheroidal shape of the earth the lengths of the degrees of latitude and longitude are different for different latitudes. As it is constantly necessary to transform differences of latitude and longitude into the corresponding linear distances on the earth's surface, extended tables for this purpose are given in the Report of the Coast and Geodetic Survey for 1884, pp. 135–321. The following values extracted from these tables show the variation in length of arcs of the meridian for latitudes from 39° to 43°:

Latitude.	Lengths of Arcs of the Meridian in Meters.		
	One degree.	One minute.	One second.
39	111013.3	1850.22	30.837
40	111032.7	1850.54	30.842
41	111052.2	1850.87	30.848
42	111071.7	1851.20	30.853
43	111091.4	1851.52	30.859

These quantities give the number of meters contained within an arc of the meridian of which the degree of latitude is the middle; thus, 111032.7 is the number of meters between latitude 39° 30′ and latitude 40° 30.′

The following values, taken from the same tables, show the variation in length of arcs of the parallel for latitudes from 39° 30′ to 42° 30.′

Latitude.	Lengths of Arcs of the Parallel in Meters.		
	One degree.	One minute.	One second.
39° 30′	86 016	1433.6	23.89
40 00	85 396	1423.3	23.72
40 30	84 770	1412.8	23.55
41 00	84 137	1402.3	23.37
41 30	83 498	1391.6	23.19
42 00	82 853	1380.9	23.01
42 30	82 201	1370.0	22.83

In the following geographical positions the values of the latitudes and longitudes which have been finally determined

which are liable to further revision are stated to seconds only. From the above tables it is seen that a thousandth of a second of latitude is about 0.03 meters or 0.1 feet.

The following are the geographical positions for the stations of the horse-shoe chain (see plate and map) which are situated in Pennsylvania. These positions have been previously published in the Reports of the Secretary of Internal Affairs for Pennsylvania for 1883 and 1884. In each case a brief statement of the location of the stations is given. The stations are marked by stone monuments, or by bolts in the rock, and are always well known by the people of the vicinity.

Rawlinsville Station.—This is situated near the village of Rawlinsville, in the eastern part of Martic township, Lancaster county.

Latitude, 39° 53′ 09.539.″ Longitude, 76° 15′ 58.372.″

To Gov. Dick,	azimuth,	156°	02′	34.80,″	distance,	48157.9 meters.
To Womelsdorf,	"	157	00	42.54	"	49061.4 "
To Beartown,	"	224	49	08.61,	"	30584.1 "
To Londonderry,	"	274	06	10.43,	"	33073.2 "
To Principio,	"	325	16	54.06,	"	39464.1 "

Londonderry Station.—This is situated in the township of the same name, in Chester county:

Latitude, 39° 51′ 50 507″. Longitude, 75° 52′ 50.442″.

To Principio,	azimuth,	19°	30′	51.92″,	distance,	31855.9 meters.
To Rawlinsville,	"	94	21	00.25,	"	33073.2 "
To Beartown,	"	154	50	11.19,	"	26637.8 "
To Meeting-house,	"	319	04	45.57,	"	22194.9 "

Beartown Station.—This is situated in Salisbury township, Lancaster county, about two miles east of Greenbank post-office:

Latitude, 40° 04′ 51.947″. Longitude, 76° 00′ 48.491″.

To Rawlinsville,	azimuth,	44°	58′	53.47″,	distance,	30584.1 meters.
To Gov. Dick,	"	116	05	56.04,	"	41916.6 "
To Womelsdorf,	"	150	11	39.68,	"	31167.0 "
To Blackspot,	"	197	38	12.38,	"	31050.6 "
To Londonderry,	"	334	45	04.08,	"	26637.8 "

Governor Dick Station.—Situated in the southern part of Cornwall township, Lebanon county:

Latitude, 40° 11′ [illegible]. Longitude, 76° [illegible].

To White Horse,	azimuth,	294°	49′	25.64″,	distance,	32925.3	meters.
To Womelsdorf,	"	248	29	12.80,	"	28763.1	"
To Beartown, .	"	295	46	48.83,	"	41916.6	"
To Rawlinsville,	"	337	55	15.34,	"	43157.9	"

Womelsdorf Station.—Situated in Heidelberg township, Lebanon county, about three miles south of the village of Newmanstown:

Latitude, 40° 19′ 28.250″. Longitude, 76° 11′ 44.689.″

To Rawlinsville,	azimuth,	7°	03′	25.96″,	distance,	49061.4	meters.
To Gov. Dick, .	"	68	39	17.79,	"	28763.1	"
To White Horse,	"	158	47	42.56,	"	22732.1	"
To Port Clinton,	"	209	08	23.76,	"	35577.7	"
To Blackspot, .	"	264	02	30.27,	"	25029.5	"
To Beartown, .	"	330	04	36.10,	"	31167.0	"

Blackspot Station.—Situated in Alsace township, Berks county, on Penn mountain, about two miles east of the city of Reading:

Latitude, 40° 20′ 51.148″. Longitude, 75° 54′ 09.864″.

To Beartown,	azimuth,	17°	42′	30.26″,	distance,	31050.6	meters.
To Womelsdorf,	"	84	13	53.08,	"	25029.5	"
To White Horse,	"	119	30	14.04,	"	37979.9	"
To Port Clinton,	"	165	18	11.61,	"	29465.5	"
To Topton, . .	"	232	13	30.51,	"	23564.1	"

White Horse Station.—Situated near the boundary line between Berks and Schuylkill counties, about five miles south of the post-office Rock:

Latitude, 40° 30′ 55.192″. Longitude, 76° 17′ 33.950″.

To Gov. Dick,	azimuth,	24°	55′	46.04″,	distance,	32925.3	meters.
To Port Clinton,	"	248	47	23.41,	"	27391.1	"
To Blackspot, .	"	299	15	03.44,	"	37979.9	"
To Womelsdorf,	"	338	48	56.10,	"	22732.1	"

Port Clinton Station.—Situated in Brunswick township, Schuylkill county, about five miles north-east of the village of Port Clinton:

Latitude, 40° 36′ 15.049″. Longitude, 75° 59′ 27.823″.

To Womelsdorf,	azimuth,	29°	16′	21.97″,	distance,	35577.7	meters.
To White Horse,	"	68	59	09.65,	"	27391.1	"
To Bake Oven, .	"	233	32	35.87,	"	26998.1	"
To Topton, . .	"	298	17	28.86,	"	29631.7	"
To Blackspot, .	"	345	14	45.21,	"	29465.5	"

Topton Station.—Situated in Longswamp township, Berks county, about four miles south of the village of Topton:

Latitude, 40° 28′ 37.491″. Longitude, 75° 40′ 58.251.″

To Blackspot,	azimuth,	52°	27′	03.70″,	distance,	23564.1	meters.
To Port Clinton,	"	118	29	30.07,	"	29681.7	"
To Bake Oven, .	"	171	50	48.86,	"	30433.3	"
To Smith's Gap,	"	209	44	07.87,	"	44239.1	"
To Big Rock, .	"	244	45	03.86,	"	22935.8	"
To Haycock, . .	"	267	59	04.69,	"	39305.5	"

Bake Oven Station.—Situated near the boundary line between Carbon and Lehigh counties, about five miles northwest of the village of Germansville:

Latitude, 40° 44′ 54.109″. Longitude, 75° 44′ 02.222″.

To Port Clinton,	azimuth,	53°	42′	39.16″,	distance,	26998.1	meters.
To Smith's Gap,	"	252	26	55.42,	"	27535.3	"
To Big Rock, .	"	309	02	01.43,	"	32277.6	"
To Topton, . .	"	351	48	49.11,	"	30433.3	"

Big Rock Station.—Situated in Salisbury township, Lehigh county, about three miles south of the city of Allentown:

Latitude, 40° 33′ 53.732″. Longitude, 75° 26′ 16.422″.

To Topton, . .	azimuth,	64°	54′	36.81″,	distance,	25935.8	meters.
To Bake Oven, .	"	129	13	35.82,	"	32277.6	"
To Smith's Gap,	"	182	33	18.74,	"	28655.5	"
To Montana, .	"	235	05	46.52,	"	38884.7	"
To Haycock, . .	"	294	32	22.86,	"	20351.4	"

Smith's Gap Station.—Situated near the boundary line between Monroe and Northampton counties, about four miles west of the village of Point Phillips:

Latitude, 40° 49′ 21.787″. Longitude, 75° 25′ 21.906″.

To Big Rock, .	azimuth,	2°	33′	54.28″,	distance,	28655.5	meters.
To Topton, . .	"	29	54	17.84,	"	44239.1	"
To Bake Oven, .	"	72	39	07.24,	"	27535.3	"
To Montana, . .	"	281	46	37.48,	"	31269.5	"
To Haycock, . .	"	335	04	45.50,	"	40889.5	"

Haycock Station.—Situated in Haycock township, Bucks county:

Latitude, 40° 29′ 18.963″. Longitude, 75° 13′ 10.341″.

To Topton, . .	azimuth,	88°	17′	07.53″,	distance,	39805.5	meters.
To Big Rock, .	"	114	40	53.66,	"	20351.4	"
To Smith's Gap,	"	155	12	42.13,	"	40889.5	"
To Montana, .	"	203	41	04.99,	"	33489.8	"
To Pickle, . .	"	250	29	52.80,	"	35527.7	"
To Goat Hill, .	"	303	28	44.11,	"	28673.6	"

The following geographical positions for four stations of the primary coast triangulation were determined about the year 1842.

Bethel Station.—Situated in Bethel township, Chester county:

Latitude, 39° 50′ 46.232″. Longitude, 75° 29′ 25.339″.

To Yard, . . .	azimuth,	211°	55′	50.45″,	distance,	16670.5	meters.
To Pine Hill, .	"	276	57	08.56,	"	42882.7	"
To Lippincott,	"	312	12	40.11,	"	20435.9	"
To Burden, . .	"	345	02	06.81,	"	36300.7	"

Yard Station.—Situated in Chester county.

Latitude, 39° 58′ 24.796″. Longitude, 75° 23′ 13.793″.

To Bethel, . .	azimuth,	31°	59′	48.83″,	distance,	16670.5	meters.
To Mt. Holly, .	"	266	12	22.78,	"	51215.8	"
To Pine Hill, .	"	299	52	41.80,	"	38898.4	"
To Lippincott,	"	347	17	38.94,	"	28585.5	"

Willowgrove Station.—Situated near the west corner of Moreland township, in Montgomery county.

Latitude, 40° 08′ 31.935″. Longitude, 75° 06′ 22.283″.

To Newtown, .	azimuth,	232°	34′	04.10″,	distance,	19892.3	meters.
To Mt. Holly, .	"	299	41	41.15,	"	31209.0	"
To Pine Hill, .	"	345	47	35.64,	"	39375.9	"

Newtown Station.—Situated in Newtown township, Bucks county.

Latitude, 40° 15′ 03.411″. Longitude, 74° 55′ 13.927″.

To Willowgrove,	azimuth,	52°	41′	15.47″,	distance,	19892.3	meters.
To Goat Hill, . .	"	171	57	31.31,	"	10638.4	"
To Mt. Rose, . .	"	232	10	19.50,	"	21153.1	"
To Stony Hill, .	"	296	34	57.01,	"	32233.9	"
To Mt. Holly, . .	"	337	47	34.42,	"	29784.1	"

The following are approximate latitudes and longitudes of primary stations to the westward and northward of the horse-shoe chain. These will be determined with greater precision when the final adjustments are made, or when additional field work is done. Hence the values are stated only to the nearest second.

Wintersdown, (York county,)	39°	49'	32"	7
Pulpit Rock, (York county,)	39	51	27	7
Round Top, (York county.)	40	06	18	7
Dauphin, (Dauphin county,)	40	21	59	7
Swatara Gap, (Lebanon county,) . . .	40	28	15	7
Bear's Head, (Schuylkill county,) . . .	40	51	01	7
Knob, (Carbon county,)	40	58	44	7
Pimple Hill, (Monroe county,)	41	01	36	7
Penobscot, (Luzerne county,)	41	10	57	7
Panther, (Luzerne county,)	41	14	09	7
Ricketts, (Sullivan county,)	41	18	31	7
Bald, (Lackawanna county,)	41	25	41	7
Moosic (Lackawanna county,)	41	27	21	7
Elk, (Susquehanna county,)	41	42	54	7

The following are the approximate latitudes tudes of a number of secondary stations and p sides the three stations in Philadelphia for whi positions are given, there are many more in th in the vicinity and along the Delaware river. T had on application to the Survey office.

	Latitude.			L
Philadelphia, State House, ...	39°	56'	55.64"	75
Philadelphia, Girard College, . . .	39	58	26 600	75
Philadelphia St. Peter's Church, . .	39	56	35.34	75
Lancaster, prison tower, ...	40	02	24.58	76
Bethlehem, Reformed Church, . . .	40	37	17	75
Lone Tree, (Carbon county,) . . .	40	48	11	75
Summit Hill, school-house tower, . .	40	49	36	75
Summit Hill, Presbyterian Church, .	40	49	33	75
Summit Hill, Catholic Church, . . .	40	49	28	75
Mt. Jefferson, South Chimney, . . .	40	49	32	75
Woodside, Catholic Church, . .	40	00	37	75
Shickshinny, (Luzerne county,)	41	09	59	76
Nanticoke, German Lutheran Church,	41	12	16	76
Wilkes Barre, St. Mary's Church, .	41	14	32	75
Bellevue, Welsh Methodist Church, .	41	24	04	75
Hyde Park, St. Patrick's Church, .	41	24	51	75
Petersburg, German Lutheran Church, ...	41	24	38	75
Providence, St. Mary's Church, . .	41	26	27	75
Olyphant, Baptist Church, . . .	41	28	23	75
No. 10. Chimney of engine house on Pa. Coal Co.'s Gravity Road, . . .	41	24	39	75
Scranton Court House, clock tower, .	41	24	29	75
Salem, (Wayne county,)	41	33	01	75

In order to make the list of geographical posi far geodetically determined in Pennsylvania n

plete, the following are given, the first and second of which are taken from the Report of the Primary Triangulation of the Lake Survey, p. 782, and the others from the Reports of the New York State Survey for 1883 and 1884:

	Latitude.	Longitude.
Edinboro', (Washington township, Erie county,) . . .	41° 52′ 28.41″	80° 10 46.88″
Erie, (Mill Creek township, Erie county,)	42 03 41.44	80 11 11.64
Bly, (Tioga county,)	41 54 35	77 00 41
Harrison, (Potter county,) . .	41 54 58	77 41 52
Athens, (Bradford county,) . .	41 57 31	76 37 00
Litchfield, (Bradford county,) .	41 59 22	76 25 49
Warren, (Bradford county,) . .	41 59 22	76 10 44

In 1884 the Philadelphia water department located the positions of several points in Bucks and Montgomery counties, starting from the line Haycock–Goat Hill as a base, and a statement of the computed positions is given in their Report for that year, page 322.

The Coast and Geodetic Survey has determined astronomically the latitude and longitude of the Capitol at Harrisburg, of the south-west corner of Pennsylvania, and of several other points upon the boundary lines of the State. The latitude and longitude of Pottsville and Wilkes Barre have been determined for the Second Geological Survey of Pennsylvania by Prof. C. L. Doolittle. The following are the values obtained:

	Latitude.	Longitude.
Harrisburg, dome of Capitol, . .	40° 15′ 51.1″	76° 52′ 54.3″
South-west corner of Pa., ...	39 43 18.19	80 31 08.20
Boundary Monument, near Smith's Ferry, ...	40 38 27.25	80 31 07.50
Wilkes Barre, Court House, . . .	41 14 40.48	75 52 57.7
Pottsville, Court House, ...	40 41 09.13	76 11 50.7

The following positions of the astronomical observatories at Allegheny and Bethlehem are taken from the *American Ephemeris and Nautical Almanac* for 1886:

	Latitude.	Longitude.
Philadelphia Old High School Observatory, ...	39° 57′ 06.0″	75° 09′ 45.2″
Allegheny Observatory, ...	40 27 41.6	80 00 43.95
Bethlehem Observatory, ...	40 36 23.9	75 22 58.5

In conclusion it may be mentioned that the above longi-

tudes are referred to the meridia
the value 77° 03′ 01.35″ as the lc
servatory at Washington, D. C.
Assistant C. A. Schott in the Rej
detic Survey for 1884, pages 407–
the more precise quantity 77° 03′
error ± 0.63.″

THE PUBLICATIONS

OF THE

GEOLOGICAL SURVEY OF PENNSYLVANIA.

FROM 1874 TO 1886.

Reports can be purchased by addressing the Geological Survey of Pennsylvania, 907 Walnut street, Philadelphia. (See page 717.)

ANNUAL REPORTS.

Annual Report of the Geological Survey of Pennsylvania, 1885, J. P. LESLEY, State Geologist. 8°, 719 pp. with preface and index, accompanied by Atlas 8°, 8 pl. and maps. 1886.

MISCELLANEOUS REPORTS.

A. A history of the FIRST GEOLOGICAL SURVEY of Pennsylvania, from 1836 to 1858, by J. P. Lesley. With the annual reports of the Board to the Legislature for 1874 and 1875. 8°, pp. 226, 1876.

B. Report on the MINERALS of Pennsylvania, by F. A. Genth; and on the hydro-carbon compounds, by S. P. Sadtler. With a reference map of the State. 8°, pp. 206, 1875.

B 2. Report on the MINERALS, by F. A. Genth, continued from page 207 to page 238. 8°, in paper cover, pp. 31, 1876. (Bound with B.)

M. Report of CHEMICAL ANALYSES in 1874–5, in the Laboratory at Harrisburg, by A. S. McCreath. 8°, pp. 105, 1875.

M 2. Report of CHEMICAL ANALYSES in 1876–8, by A. S. McCreath; Classification of coals, by P. Frazer; Fire-brick tests, by F. Platt; Dolomitic limestone beds, by J. P. Lesley; Utilization of anthracite slack, by F. Platt; Determination of Carbon in iron or steel, by A. S. McCreath. With one folded plate (section at Harrisburg) and four page plates. 8°, pp. 438, 1879.

M 3. Report of CHEMICAL ANALYSES in 1879–80, by A. S. McCreath. With a reference map of 93 iron ore mines in the Cumberland valley. 8°, pp. 126, 1881.

N. Report on the LEVELS above tide of railroad, canal, and turnpike stations, mountain tops, &c., in and around Pennsylvania, in 200 tables, by C. Allen. With a map. 8°, pp. 279, 1878.

O. CATALOGUE of specimens collected by the survey, (No. 1 to No. 4,264,) by C. E. Hall. 8°, pp. 217, 1878.

O 2. CATALOGUE (continued from No. 4,265 to No. 8,974); also catalogue of fossils, (pp. 231 to 239.) 8°, pp. 272, 1880.

P. Report on the COAL FLORA of Pennsylvania and the United States, Vols. 1 and 2, (bound together,) by L. Lesquereux. 8°, pp. 694, 1880.

P. Report on the COAL FLORA of Pennsylvania and the United States, Vol. 3, with 24 double page plates (lithographed) of coal plants, to accompany P., Vols. 1 and 2. 8°, pp. 283, 1884.

(**P.**) ATLAS of 87 double page plates (lithographed) of coal plants, to accompany P., Vols. 1 and 2. 8°, 1879.

P 2. Report on Permo-Carboniferous plants from W. Va. and Greene county, Pennsylvania, by W. M. Fontaine and I. C. White. With 38 double page plates (lithographed.) 8°, pp. 143, 1880.

P 3. Description of *Ceratiocaridæ*, by C. E. Beecher; and of *Eurypteridæ*, by James Hall. With 8 plates. 8°, pp. 39, 1884.

Z. Report on the TERMINAL MORAINE across Pennsylvania, by H. C. Lewis; including extracts from descriptions of the Moraine in New Jersey, by G. H. Cook, and in Ohio, Kentucky, and Indiana, by G. F. Wright. With a map of the State, 18 photographic views of the Moraine, and 32 page plate maps and sections. 8°, pp. lvi and 299, 1884.

GRAND ATLAS, Div. I, Pt. I, 1885, port-folio containing maps of 56 counties and parts of counties (scale 2 miles to 1 inch) on 49 sheets (26″×32″.) The maps of the remaining counties will be published in Part II. These maps are duplicate prints on heavy paper of the county maps contained in the reports of progress.

ANTHRACITE REGION.

A 2. Report on the causes, kinds, and amount of WASTE in mining anthracite, by F. Platt; with a chapter on METHODS of mining, by J. P. Wetherill. Illustrated by 35 figures of mining operations, a plan of the Hammond breaker, and a specimen sheet of the maps of the Anthracite coal fields. 8°, pp. 134, 1881.

AC. Report on MINING METHODS, &c., in the anthracite coal fields, by H. M. Chance. Illustrated with 54 plates and 60 illustrations in the text. 8°, pp. 574, 1883.

(**AC.**) ATLAS containing 25 plates illustrating coal mining, to accompany Report AC, by H. M. Chance. 8°, 1883.

AA. First report of progress of the anthracite survey; PANTHER CREEK BASIN, by C. A. Ashburner; with a determination of the latitude and longitude of Wilkes Barre and Pottsville, by C. L. Doolittle; and a theory of stadia measurements, by A. Winslow. 8°, pp. 407, 1883.

AA. Second report of progress of the anthracite survey, Part I; Statistics of Production and Shipment for 1883 and 1884. Charles A. Ashburner, geologist in charge.

(**AA.**) ATLAS of SOUTHERN anthracite field, Part I, containing 13 sheets: 3 geological and mine sheets, 3 cross section sheets, 3 columnar section sheets, 1 topographical map sheet, and 1 coal bed area sheet, relating to the PANTHER CREEK BASIN; 1 general map of the anthracite region, and 1 chart of anthracite production from 1820 to 1881. 8°, 1882. Chas. A. Ashburner, geologist in charge; A. W. Sheafer and Frank A. Hill, assistant geologists.

NOTES.—Single sheets of the anthracite survey, with the exception of those in the Panther Creek atlas, can be purchased by addressing Chas. A. Ashburner, geologist in charge, 907 Walnut street, Philadelphia.

sheets: 4 geological and mine sheets between Delano and Locust Dale, 3 topographical sheets between Quakake Junction and Mount Carmel, and 4 cross section sheets. 8°, 1884. Charles A. Ashburner, geologist in charge; A. W. Sheafer and Bard Wells, assistant geologists.

(AA) ATLAS of NORTHERN anthracite field, Part I, containing 6 geological and mine sheets between Wilkes Barre and Nanticoke, 3 cross section sheets, and 4 columnar section sheets. 8°, 1885. Charles A. Ashburner, geologist in charge; Frank A. Hill, assistant geologist.

(AA.) ATLAS EASTERN MIDDLE anthracite field, Part I, containing 8 sheets—2 geological and mine sheets in the vicinity of Hazleton, Drifton, and surrounding towns, 3 cross section sheets, and 3 columnar section sheets. 8°, 1885. Charles A. Ashburner, geologist in charge; A. P. Berlin and Arthur Winslow, assistant geologists.

GRAND ATLAS, Div. II, Pt. I, 1884. Port-folio containing 26 sheets, (26"× 32",) as follows: 13 sheets Atlas Southern Anthracite Field, Part I, 11 sheets, Atlas Western Middle Anthracite Field, Part I, 1 sheet photo views of plaster models in Western, Middle, and Southern Fields, and 1 specimen sheet, Report A 2.

GRAND ATLAS, Div. II, Pt. II, 1885. Port-folio containing 22 sheets, (26"× 32",) as follows: 13 sheets Atlas Northern Anthracite Field, Part I, 8 sheets Atlas Eastern Middle Anthracite Field, Part I, and 1 sheet containing a preliminary general map of the Anthracite Coal Fields and adjoining counties.

For anthracite coal in SULLIVAN county, see G 2, and Annual Report, 1885.

For Conglomerate beds near Carbondale, Pittston, &c., see G 5, G 7.

For Utilization of anthracite slack, see M 2.

For General Description anthracite region, Quaternary Geology of the Wyoming-Lackawanna Valley, &c., &c., see Annual Report, 1885.

BITUMINOUS COAL FIELDS AND SURROUNDING AREAS.

H. First report on CLEARFIELD and JEFFERSON counties, by F. Platt. With 8 maps, 2 sections, and 139 cuts in the text. 8°, pp. 296, 875. (*For second report see H 6, H 7.*)

H 2. Report on CAMBRIA county, by F. & W. G. Platt. With 4 maps and sections and 84 cuts in the text. 8°, pp. 194, 1877.

H 3. Report on SOMERSET county, by F. & W. G. Platt. With 6 maps and sections and 110 cuts in the text. 8°, pp. 348, 1877.

H 4. Report on INDIANA county, by W. G. Platt. With a colored geological county map and 87 cuts in the text. 8°, pp. 316, 1878.

H 5. Report on ARMSTRONG county, by W. G. Platt. With a colored geological county map and 58 cuts in the text. 8°, pp. 338, 1880.

H 6. Second report on JEFFERSON county, (*See H above,*) by W. G. Platt. With a colored geological county map and 57 cuts in the text. 8°, pp. 218, 1881.

H 7. Second report on CLEARFIELD county, (*See H above,*) by H. M. Chance. With a colored geological county map, an outcrop map of the Houtzdale basin, and 58 cuts in the text. 8°, pp. 197, 1884.

I. Report on VENANGO county, by J. F. Carll. The geology around Warren, by F. A. Randall. Notes on the comparative geology of N. E. Ohio, N. W. Pa., and W. New York, by J. P. Lesley. With one small map of the Venango oil region, one small map of the region south and east of Lake Erie, one long section of the rocks at Warren, and 7 cuts in the text. 8°, pp. 127, 1875.

I 2. Report of oil well records and levels in VENANGO, WARREN, CRAWFORD, CLARION, ARMSTRONG, BUTLER, &c., by J. F. Carll. 8°, pp. 398, 1877.

I 3. Report on the VENANGO, WARREN, CLARION, and BUTLER OIL REGIONS; descriptions of rig, tools, &c.; survey of the Garland and Panama conglomerates, &c.; discussion of pre-glacial and post-glacial drainage, by J. F. Carll. With 23 page plates and an atlas. 8°, pp. 482, 1880.

(I 3.) ATLAS of 22 sheets. Map of Venango county, colored geologically; map of lower oil field (Butler, Armstrong, and Clarion,) in two sheets; 3 local contour maps at Franklin, Titusville, and Spring Creek; two maps of N. W. Pennsylvania, showing the past and present drainage; long section across W. Pennsylvania; vertical section of the formations from the Upper Coal Measures down to the bottom of the Devonian; diagram map and section of Third sand; profile section from Meadville, S. W.; 5 sheets of grouped oil well sections; 5 sheets of working drawings for well boring, &c.; diagram of daily rate of drilling six wells at Petrolia.

I 4. Report on WARREN county, by J. F. Carll. With a colored geological county map, a map of the Warren oil region, and 2 sheets of oil well sections. 8°, pp. 439, 1883. (*Note.—The first 147 pages of this book contain oil well records; see under Petroleum Fields below.*)

J. Report on the OIL REGION, by H. E. Wrigley; map and profile of line of levels through Butler, Armstrong, and Clarion, by D. J. Lucas; map and profile of Slippery Rock creek, by J. P. Lesley. 5 maps and sections, a plate and 5 cuts. 8°, pp. 122, 1875.

K. Report on GREENE and WASHINGTON counties, by J. J. Stevenson. With two county maps. (Showing the calculated local depths of the Pittsburgh and Waynesburg coal beds beneath the surface,) and 3 page plates of general sections. 8°, pp. 419, 1876. (*Note.—Since the publication of this book two colored geological county maps have been published, and will be found in pocket of volume K 3 described below.*)

K 2. First report on FAYETTE, WESTMORELAND, and S. E. ALLEGHENY counties, (*i. e.*, west of Chestnut Ridge,) by J. J. Stevenson. With 3 colored geological county maps and 50 cuts in the text. 8°, pp. 437, 1877.

K 3. Second report on FAYETTE and WESTMORELAND counties, (the Ligonier valley,) by J. J. Stevenson. With 4 page plates, and 107 cuts in text. 8°, pp. 331, 1878. (*Note.—In a pocket in this volume will be found the colored geological maps of Greene and Washington counties, alluded to above.*)

K 4. Pt. I, Report on the MONONGAHELA river COAL MINES, from the West Virginia State line to Pittsburgh, (including some on the Youghiogheny and other streams,) by J. Sutton Wall. With a map of the region in a pocket, 12 heliotype pictures, and 26 page plates. 8°, pp. 231, 1884.

L. Report on the YOUGHIOGHENY coke manufacture, by F. Platt; Notes on the coal and iron ore beds, by C. A. Young; Report on methods of coking, by J. Fulton, (*See G* below;) Report on the use of natural gas in the iron manufacture, by J. B. Pearse and F. Platt; The Boyd's hill gas well at Pitts-

coke ovens, and page plates and cuts in the text. 8°, pp. 252, 1876.

Q. Report on BEAVER, N. W. ALLEGHENY, and S. BUTLER counties, by I. C. White. With 3 colored geological county maps, and 21 page plates of sections. 8°, pp. 337, 1878.

Q 2. Report on LAWRENCE county, and special Report on Correlation of the Pennsylvania and Ohio coal beds, by I. C. White. With a colored geological county map, and 134 cuts in the text. 8°, pp. 336, 1879.

Q 3. Report on MERCER county, by I. C. White. With colored geological county map, and 119 cuts in the text. 8°, pp. 233, 1880.

Q 4. Report on CRAWFORD and ERIE counties, by I. C. White. With two colored geological county maps, and 107 cuts in the text. Also, a Report on a preglacial outlet for Lake Erie, by J. W. Spencer. With two maps of the Lake region. 8°, pp. 406, 1881.

R. Report on McKEAN county, and its geological connections with Cameron, Elk, and Forest counties, by C. A. Ashburner. With 33 page plates of vertical and columnar sections, pictures of Rock city and Olean conglomerate, Wilcox and Kane spouting wells, map of Howard Hill coal field, &c., and an atlas of 8 sheets. 8°, pp. 371, 1880.

(R.) ATLAS for McKean county of 8 sheets:—Colored geological county map; three topographical maps; of Buffalo Coal Company tract, Alton coal basin, and Potato Creek coal basin; map of McKean oil district; one sheet of columnar sections between Bradford and Ridgway; and 2 diagram sheets of the Well account and Production account in the Bradford district.

R 2. Part II, Report on township geology of CAMERON, ELK AND FOREST counties, by C. A. Ashburner.

(R 2.) ATLAS for CAMERON, ELK AND FOREST counties, of 11 sheets (*published November, 1884, in advance of the report*):—3 colored geological county maps; 1 anticlinal and synclinal map; 1 topographical map McKean county; 2 tract maps Forest and Elk counties; 1 map Straight Creek coal basin; 2 sheets oil well sections; and 1 sheet coal sections.

V. Report on N. BUTLER county; and (Part 2) special report on the Beaver and Shenango river coal measures, by H. M. Chance. With a colored geological map of N. Butler; a contour local map around Parker; a map of the anticlinal rolls in the 6th basin; a chart of the Beaver and Shenango rivers; profile section from Homewood to Sharon; Oil well records and surface sections; and 154 cuts in the text. 8°, pp. 248, 1879.

V 2. Report on CLARION county, by H. M. Chance. With a colored geological county map; a map of the anticlinals and oil-belt; a contoured map of the old river channel at Parker; 4 page plates, and 83 cuts in the text. 8°, pp. 232, 1880.

For the coal basins of BRADFORD and TIOGA counties see report G.
For the coal basins of LYCOMING and SULLIVAN see report G 2.
For the coal basins of POTTER county see G 3.
For the coal basins of CLINTON county see G 4.
For the coal in WAYNE county see G 5.
For the East Broad Top coal basin in HUNTINGDON county see F.
For the mountain coals in BLAIR county see T.
For the Broad Top coal measures in BEDFORD and FULTON counties see T 2.
For the coal basins in CENTRE county see T 4.
For coal analyses, see M, M 2, M 3.

For coal plants, see P, P 2.

For fossil crustaceans in coal slate, see P 3.

For Origin of Coal; Pittsburgh Region and Monongahela Valley; Wellersburg coal basin, Somerset county; and Tipton Run coal-beds, Blair county, see Annual Report, 1885.

Grand Atlas Div. III, Pt. I, 1885, port-folio containing 35 sheets (26″×32″) as follows: 32 sheets relating to portions of the Petroleum and Bituminous Coal-fields, and 3 sheets relating to the Quaternary period.

PETROLEUM AND GAS.

See reports I, I 2, I 3, I 4, and J, under Bituminous Coal Fields.

See L, for the Pittsburgh gas well, and the use of gas in the iron manufacture.

See Q, Q 2, Q 3, Q 4, for references to oil rocks in Beaver, Lawrence, Mercer, Crawford, Erie, and S. Butler counties.

See K for the Dunkard Creek oil wells of Greene county.

See R, R 2, for descriptions of oil rocks in McKean, Elk, and Forest counties.

See V, V 2, for notes on the oil rocks of N. Butler and Clarion counties.

See H 2 for oil boring at Cherry Tree, Cambria county.

See G 5 for oil boring in Wayne county.

See Annual Report, 1885, for report of progress in the oil and gas region, with special facts relating to the geology and physics of natural gas.

See Grand Atlas, Div. III, Pt. I, under Bituminous Coal Fields.

NORTH-EASTERN AND MIDDLE PENNSYLVANIA.

(*Palæozoic formations from the Coal Measures down.*)

D. First report on LEHIGH county iron mines, by F. Prime. With a contour line map of the ore region and 8 page plates. 8°, pp. 73, 1875.

D 2. Second report on LEHIGH county iron mines, by F. Prime. With a colored geological contour line map of the iron region, (in 4 sheets,) a colored geological contour line map of the Ironton mines, 4 double page lithograph pictures of Limestone quarries, and one page plate of *Monocraterion*. 8°, pp. 99, 1878.

D 3. Vol. 1. Report on LEHIGH and NORTHAMPTON counties. Introduction by J. P. Lesley; Slate belt, by R. A. Saunders; Limestone belt and iron mines, by F. Prime; South mountain rocks, by F. Prime and C. E. Hall. With 3 lithograph pictures of quarries, 4 pictures of triangulation stations, 14 page plates of sections, and an atlas of maps. 8°, pp. 283, 1883. (*Note.—For atlas see below.*)

D 3. Vol. 11, Part I. Report on BERKS county, (*outh mountain belt*,) by E. V. d'Invilliers. With 10 page plates of sections and Indian relics, and 3 pictures of rock exposures. 8°, pp. 441, 1883. (*Note.—For atlas see below.*)

(**D 3.**) ATLAS: One colored geological map of *Lehigh* and Northampton counties, (*one sheet*;) one colored geological contour line map of Southern Northampton county, (*six sheets*;) a contour line map of the mountains from the Delaware to the Schuylkill, (*eighteen sheets*;) a colored geological contour line index map to the 22 sheets, (*one sheet*,) and 4 sheets of maps of Iron mines.

LIN, and ADAMS, (*three sheets*); and first instalment of contour line map of the South mountains, Sheets A 1, A 2, B 1, B 2, (*four sheets*,) by A. E. Lehman.

F. Report on the JUNIATA RIVER district in MIFFLIN, SNYDER and HUNTINGDON counties, by J. H. Dewees, and on the Aughwick valley and East Broad Top region in HUNTINGDON county, by C. A. Ashburner. With colored geological maps of East Broad Top R. R. and Orbisonia vicinity, (2 sheets;) Three Springs map and section, (2 sheets;) Sideling Hill Creek map and section, (2 sheets,) and isometric projection at Three Springs, (1 sheet:) six folded cross sections and 22 page plates of local maps and columnar sections. 8°, pp. 305, 1878.

F 2. Report on PERRY county, (*Part I, geology*,) by E. W. Claypole. With two colored geological maps of the county; 17 geological outline township maps as page plates, and 30 page plate cross and columnar sections. 8°, pp. 437, 1884.

G. Report on BRADFORD and TIOGA counties, by A. Sherwood; report on their coal fields,) including forks of Pine creek in Potter county,) by F. Platt; report on the COKING of bituminous coal, by J. Fulton. (*See L above.*) With two colored geological county maps, 3 page plates, and 35 cuts in the text. 8°, pp. 271, 1878.

G 2. Report on LYCOMING and SULLIVAN counties; field notes by A. Sherwood; coal basins by F. Platt. With two colored geological county maps, (of Lycoming and Sullivan,) a topographical map (in two sheets) of the Little Pine creek coal basin, and 24 page plates of columnar sections. 8°, pp. 268, 1880.

G 3. Report on POTTER county, by A. Sherwood. Report on its COAL FIELDS, by F. Platt. With a colored geological county map, 2 folded plates, and 2 page plates of sections. 8°, pp. 121, 1880.

G 4. Report on CLINTON county, by H. M. Chance, including a description of the Renovo coal basin, by C. A. Ashburner, and notes on the Tangascootac coal basin, by F. Platt. With a colored geological county map, 1 sheet, of sections, local Renovo map, 6 page plates, and 21 sections in the text. 8°, pp. 183, 1880.

G 5. Report on SUSQUEHANNA and WAYNE counties, by I. C. White. With a colored geological map of the two counties and 58 cuts in the text. 8°, pp. 243, 1881.

G 6. Report on PIKE and MONROE counties, by I. C. White. With two colored geological county maps, (1 sheet Pike and Monroe and 1 sheet Wyoming,) a map of glacial scratches, and 7 small sections. Report on the Delaware and Lehigh Water Gaps, with two contoured maps and five sections of the gaps, by H. M. Chance. 8°, pp. 407, 1882.

G 7. Report on WYOMING, LACKAWANNA, LUZERNE, COLUMBIA, MONTOUR, and NORTHUMBERLAND counties, (*i. e.*, the parts lying *outside* of the anthracite coal fields,) by I. C. White. With a colored geological map of these counties, (in two sheets,) and 31 page plates in the text, 8°, pp. 464, 1883. (*Note.—The colored geological map of* WYOMING *county is published in G 6.*)

T. Report on BLAIR county, by F. Platt. With 35 cuts in the text, and an Atlas of maps and sections, (see below.) 8°, pp. 311, 1881.

(T.) Atlas of colored geological contour line map of Morrison's cove, Canoe valley, Sinking valley, and country west to the Cambria county line,

8°, 1881.

T 2. Report on BEDFORD and FULTON counties, by J. J. Stevenson. With two colored geological maps of the two counties. 8°, pp. 382, 1882.

T 3. Report on HUNTINGDON county, by I. C. White. With a colored geological map of the county, and numerous sections. 8°, pp. 471, 1885.

T 4. Report on CENTRE county, by E. V. d'Invilliers; also, special report, by A. L. Ewing, and extracts from report to Lyon, Shorb & Co., by J. P. Lesley. With a colored geological map of the county, 13 page plates of local maps and sections, and 15 cuts in the text. 8°, pp. 464, 1884.

For report on line of the Terminal Moraine, see Z.

GRAND ATLAS, Div. IV, Pt. I, 1885. Port-folio containing 43 sheets, as follows: 30 sheets relating to the Durham and Reading Hills and bordering valleys in Northampton, Lehigh, Bucks, and Berks counties, and 13 sheets relating to the South Mountains in Adams, Franklin, Cumberland and York counties.

GRAND ATLAS, Div. V, Pt. I, 1885. Port-folio containing 35 sheets, as follows: 29 sheets relating to the Topography and Geology of the Palæozoic strata in parts of Cambria, Blair, Bedford, Huntingdon, Mifflin, Centre, and Union counties, 5 sheets contain a map and geological cross section along the east bank of the Susquehanna river, Lancaster county, and 1 sheet contains cross sections of the Philadelphia belt of the Azoic rocks.

For report on Cornwall Iron Ore Mines, Lebanon county, and the Tipton Run coal-beds, Blair county, see Annual Report, 1885.

SOUTH-EASTERN PENNSYLVANIA.

C. Report on YORK and ADAMS counties, by P. Frazer. With one folded map of a belt of York county through York and Hanover, 6 folded cross sections, and two page plate microscopic slices of dolerite. 8°, pp. 198, 1876. (*Note. The colored geological county map of* YORK *is published in the* ATLAS *to C 3.*)

C 2. Report on YORK and ADAMS counties, (South Mountain rocks, iron ores, &c.,) by P. Frazer. With one general map of the district, 10 folded cross sections, and 5 page plates. 8°, pp. 400, 1877. (*Note. The colored geological county map of* ADAMS *is published in D 5.*)

C 3. Report on LANCASTER county, by P. Frazer. With nine double page lithographic views of slate quarries and Indian-pictured rocks, one plate of impressions on slate, and one page plate microscopic section of trap, and an atlas. 8°, pp. 350, 1880.

(**C 3.**) ATLAS of 13 sheets: Colored geological map of York county; colored geological map of LANCASTER county; Susquehanna river section, (Sheets 1, 1 A, 2, 2 A, 3, 4;) Lancaster section; Pequea section; Muddy run section; Chestnut Hill mines; Gap Nickel mine.

C 4. Report on CHESTER county; General Description, pp. 214, by J. P. Lesley; Field Notes in the townships, pp. 215-354, by P. Frazer. With a colored geological county map, a photographic view of contorted schists, and 12 page plates. 8°, pp. 394, 1883.

C 5. Report on DELAWARE county, by C. E. Hall. With a colored geological county map; a contour line map around Media; 30 photographic page plate views of granite quarries, kaolin pits, &c., and 4 page plates of altered micas. 8°, pp. 128, 1885. See Annual Report, 1885, for Kaolin Report.

C 6. Report on PHILADELPHIA and the southern parts of MONTGOMERY and BUCKS counties, by C. E. Hall. With a colored geological map of the belt of country between Trenton and Delaware county, (in 3 sheets,) a sheet of colored cross sections, and 24 cuts in the text. 8^{O}, pp. 145, 1882.

E. Part I of (historical introduction to) a report on the AZOIC rocks, by T. S. Hunt. 8^{O}, pp. 253, 1878.

For report on the kaolin deposits of CHESTER and DELAWARE counties, see Annual Report, 1885.

See also GRAND ATLAS, Div. V, Pt. I, under North-eastern and Middle Pennsylvania.

SALE OF SURVEY PUBLICATIONS.

In accordance with the provisions of an act approved July 3, 1885, the Survey Reports printed prior to that date, remaining in the custody of the Board of Commissioners, have been turned over (1) to the State Librarian for distribution and exchange with other States and Territories, and (2) to the proper officials for delivery to the members of the Legislature of 1885. That portion of the act of May 14, 1874, directing the sale of these reports *at cost of publication to all applicants for them* has been repealed.

In consequence, the Board of Commissioners have no reports on hand for sale through the Secretary of Internal Affairs as formerly; an arrangement has, however, been made for the accommodation of persons wishing any of the reports published from 1874 to 1885, inclusive, by which copies will be purchased at the Survey Office, as opportunity will permit, and be resold at the following prices, to all applicants for them:

		Price.	*Postage.*
A.	History of the First Geological Survey, 1876,	$0 25	$0 06
A^2.	Coal Waste, 1881,	1 10	12
AC.	Mining Methods, with Atlas, 1883,	2 80	37
AA.	Panther Creek Anthracite Field, 1883,	58	18
AA.	Panther Creek Anthracite Field Atlas, Pt. 1, 1883,	1 50	12
AA.	Mahanoy and Shenandoah Anthracite Field Atlas, Part 1, 1884,	1 65	11
AA.	Wilkes Barre and Nanticoke Anthracite Field, Pt. 1, 1884,	2 42	12
AA.	Hazleton and Drifton Anthracite Field Atlas, Pt. 1, 1885,	1 50	8
AA.	Anthracite Statistics for 1883 and 1884, with map of the Coal Regions, 1885,	15	2
B.	Mineralogy of Pennsylvania, 1875,	75	10
C.	York and Adams Counties, 1876,	85	10
C^2.	York and Adams Counties, 1877,	1 25	12
C^3.	Lancaster County, with Atlas, 1880,	2 20	25
C^4.	Chester County, 1883,	75	18
C^5.	Delaware County, 1885,	1 15	13
C^6.	Philadelphia and parts of Montgomery and Bucks Counties, 1882,	1 65	13
D.	Lehigh County Iron Mines, 1875,	50	4
D^2.	Lehigh County Iron Mines, 1878,	1 60	12

NOTE.—Single copies of the anthracite sheets contained in the above atlases can be purchased at the cost of printing.

D^2.	Vol. I, Lehigh and Northampton Counties, 1883,	[illegible]	[illegible]
D^3.	Vol. II, Part 1, Berks County, 1883,	53	18
D^4.	Atlas Lehigh and Northampt n Counties,	2 80	17
D^5.	Atlas—Cumberland, Franklin, and Adams Counties,	1 25	8
E.	Trap Dykes and Azoic Rocks of S. E. Pennsylvania, 1878,	48	12
F.	Mifflin, Snyder, and Huntingdon Counties, 1878,	2 55	20
F^2.	Perry County, 1884,	90	17
G.	Bradford and Tioga Counties, 1878,	1 00	12
G^2.	Lycoming and Sullivan Counties, 1880,	1 06	14
G^3.	Potter County, 1880,	58	8
G^4.	Clinton County, 1880,	1 05	12
G^5.	Susquehanna and Wayne Counties, 1881,	70	13
G^6.	Pike and Monroe Counties, 1882,	1 15	15
G^7.	Wyoming, Lackawanna, Luzerne, Columbia, Montour, and Northumberland Counties, 1883,	85	20
H.	Clearfield and Jefferson Counties, 1875,	1 50	13
H^2.	Cambria County, 1877,	1 00	12
H^3.	Somerset County, 1877,	85	18
H^4.	Indiana County, 1878,	80	14
H^5.	Armstrong County, 1880,	75	16
H^6.	Jefferson County, 1881,	60	12
H^7.	Clearfield County, 1884,	85	11
I.	Venango County, 1875,	60	5
I^2.	Oil Well Records in Venango, Warren, Crawford, Clarion, Armstrong, Butler, &c., 1877,	60	18
I^3.	Venango, Warren, Clarion, and Butler Oil Regions, with Atlas, 1880,	2 30	30
I^4.	Warren County, 1883,	1 12	20
I^5.	Map of the Oil Regions, 1885,	10	2
J.	Oil Regions, 1875,	75	6
K.	Greene and Washington Counties, 1876,	65	16
K^2.	Fayette, Westmoreland, and S. E. Allegheny Counties, 1877,	1 40	20
K^3.	Fayette and Westmoreland Counties, 1878,	1 40	16
K^4.	Monongahela River Coal Mines, Pt. 1, 1884,	1 15	14
L.	Coke Manufacture and the Use of Natural Gas in Iron Making, 1876,	1 00	13
M.	Chemical Analyses in 1874–5, 1875,	50	5
M^2.	Chemical Analyses in 1876–8, 1879,	65	18
M^3.	Chemical Analyses in 1879–80, 1881,	40	10
N.	Tables of Elevations in Pennsylvania, 1878,	70	15
O.	Catalogue of Specimens in Geological Museum, 1878,	40	10
O^2.	Catalogue of Specimens in Geological Museum, 1880,	40	10
P.	Vols. I and II, Coal Flora of Pennsylvania and United States, 1880,	80	28
P.	Vol III, Coal Flora of Pennsylvania and United States, 1884,	1 20	18
P.	Atlas of Coal Flora of Pennsylvania and United States, 1879,	3 35	22
P^2.	Permian Flora of West Virginia and S. W. Pennsylvania, 1880,	2 25	17

		Price.	Postage.
P³.	Description of the Fossils *Ceratiocaridæ* and *Eurypteridæ*, 1884,	60	7
Q.	Beaver, N. W. Allegheny, and S. Butler Counties, 1878,	1 40	20
Q².	Lawrence County, 1879,	70	15
Q³.	Mercer County, 1880,	60	11
Q⁴.	Crawford and Erie Counties, 1881,	1 17	18
R.	McKean County, with Atlas, 1880,	1 70	22
R².	Cameron, Elk, and Forest Counties, Part II, with Atlas, 1885,	1 25	25
T.	Blair County, with Atlas, 1881,	4 55	28
T².	Bedford and Fulton Counties, 1882,	80	20
T³.	Huntingdon County, 1885,	95	18
T⁴.	Centre County, 1884,	80	18
V.	North Butler County, 1879,	70	15
V².	Clarion County, 1880,	43	12
X.	Geological Atlas of Counties, 1885,	4 45	18
Z.	Terminal Moraine in Pennsylvania and Western New York,	1 40	16

GRAND ATLASES.

These atlases contain maps and sections printed on heavy paper (sheets 26"×32") of similar maps and sections printed on light paper sheets contained in the octavo atlases.

Division I, Part I, Geological maps of 56 counties.

Division II, Part I, Anthracite Coal-fields.

Division II, Part II, Anthracite Coal-fields.

Division III, Part I, Petroleum and Bituminous Coal-fields.

Division IV, Part I, Durham and Reading Hills and South Mountains.

Division V, Part I, Central and South-eastern Pennsylvania.

Price of complete set, (6 vols.,) $36 00.

INDEX.

Page.

Abbott coal-bed, where mined, ... 368
Abbott and Jackson twps., Potter co., borings for oil in, ... 82
Academy of Natural Sciences, Phila., Survey specimens deposited with, 441
Act of Assembly authorizing continuation of oil survey, ... 1
Adachi, Jinzoo, connected with work in Northern Coal Field, ... 354
Albite in feldspar rocks, ... 585
Alden colliery, coal-bed worked at, ... 368
" " elevations at, ... 374
Alden, P. E., map of property State Line and Sullivan R. R. Co., . . . 463
Alden, P. E., surveys of Bernice mines, ... 473
Allegany Oil District, N. Y., ... 12
" " " " immense flow of gas in, ... 31
" " " " pressure of gas in, ... 39
" " " " statistics of, ... 14
Allegany and Bradford black oil-sands, ... 3
Allegany co., N. Y., to St. Joe, Butler co., Pa., oil drillings between, . . 3
Allegheny co., Pa., elevations, ... 142
" " wells, gas from Venango-Butler oil-sands, ... 4
" observatory, geographical position of, ... 706
Alleghenies, triangulation extending to foot of, ... 698
Allegheny Valley R. R., elevations along, ... 140
Allen twp., Washington co., elevations in, ... 152
Allaphane, found at Cornwall, ... 547
Allorisma subcuneata, ... 444,456,457
Alluvial drift between Kingston and Wilkes Barre, ... 387
Alsing clay mills, ... 613
American Assn., Szabo's feldspar test, proceedings of, ... 587
" Inst. of Min. Engrs., Hoosac tunnel, rock decribed in Trans., . 578
" Journal of Science, Hoosac tunnel, rock described in, . 578,580,581
" American Kaolin Works, Chester co., ... 572
" Philosophical Society, ... 579
" Glacial Geology, paper on, ... 624
" Philos. Soc., paper on Substance Found in Peat-bog, ... 648
Analyses coals from Hauto screen building, L. C. & N. Co., ... 316
" " Lehigh region, ... 310
" " Panther creek basin, ... 310
" Penna. anthracites, ... 313
" specimens from Mammoth bed mines, ... 311
" Bernice bed A, ... 467
" " coal-beds, ... 477–485
" bituminous coal, Kramer & Hart mine, (Tipton,) 264
" Loyalsock coal, ... 318

Page.
Analyses coal from Tipton run tunnel, ... 265
" Pocono coals, remarks on, ... 268
" " blue ore," Phœnix mines, ... 537
" Cornwall ore compared with Boyertown ore, etc., ... 537
" Dillsburg ore compared with Cornwall ore, ... 537
" hematite ore, (Jerome L. Boyer,) 536
" Island mine ore compared with Cornwall ore, ... 537
" Wheatfield mine ore " " " " 537
" Hockessin clay, ... 587
" John's kaolin, ... 589
" *dopplerite*, ... 651,655
" kaolin from Lancaster co., ... 588
" mineral associated with Cornwall ore, ... 538
" material found in peat-bogs, ... 116
" trap rock, ... 497
Anthracite coal fields, areas of, ... 277
" " general description of, ... 269
" coal in Pennsylvania, origin of, ... 115
" counties, relative importance of, ... 276
" furnace, Cornwall, ... 543
" region, geography of, ... 275
" " history of, ... 277
" " policy adopted in surveying, ... 271
" survey, date of completion of work, ... 272
" " original plan of field operation, ... 273
" " size of field corps, ... 271
Anticlinals and Basins in Northern Anthracite coal-field, ... 398
" " Wyoming valley, ... 404
" not a guide in searching for oil, ... 73
" system of naming used on Survey, ... 405
" theory, remarks on, ... 45-51
Apollo basin and sub-axis, ... 167
Archbald pot-holes, ... 615-618
" " formed in pre-glacial times, ... 636
Archer well, Elk co., ... 3
Armstrong co., gas in central portion of, ... 36
Artesian wells of Paris, ... 665
Ashburner, Charles A., description of Archbald Pot Hole, by, ... 615
" " report on Bernice coal-basin, by, ... 459
" " " Brandywine Summit kaolin bed, by, . 593
" " " Wyoming Valley limestone beds, by, . 437
" " " limestone with kaolin, ... 581
" " measurements of Ernhout and Taylor well, by, . 663
" " notice of Scranton mineral, by, ... 655
" " Wilcox Well, No. 1, studied by, ... 664
Ashland and Delano, rock sections between, ... 335
" difficulty in survey east and west of, ... 346
" mine sheet (No. IV,) area of, ... 343
" " " coal-beds worked on, ... 343
" " " section showing coal measures on, . . . 343

Ashley cemetery anticlinal, ... 415
" (Nos. 6 and 8) collieries, elevations at, ... 383
" mine, Red Ash bed, worked at, ... 381
" mine sheet, No. VI, description of, ... 381
" planes, Pottsville Conglomerate along, ... 287,393
" shops anticlinal, description of, ... 415
Atlantic mines, description of, ... 204
Athens, Bradford co., geographical position of, ... 706
Athyris subquadrata, ... 440,453
Augusta Springs, Va., Pocono coal mined at, ... 254
Aussee, Austria, peat-bog near, ... 652
Aviculopecten occidentalis, ... 442,455
" *winchelli*, ... 442,444,453
Avondale colliery, operator, and beds worked at, ... 366
" " elevations at, ... 379
Azimuth, definition of, ... 698
Azurite, found at Cornwall, ... 547

B.

B coal-bed, Loyalsock Field, analysis of, ... 318
Baby tunnel, Harry E. colliery, ... 386
" coal-bed, where mined, ... 369
Bagdad anticlinal axis, ... 165
Bald mountain, ... 459
Baldridge oil district, ... 24
Bald triangulation station, geographical position, ... 697,705
Baldwin twp., Allegheny co., elevations in, ... 144
Baltic Sea, formation of bogs near mouth of, ... 115
Baltimore bore-hole, section of, ... 485,486
" coal-bed, where mined, ... 368,372
" " one bench worked, ... 382
" " average thickness of, ... 392
" " near Wilkes Barre, ... 391
" " original purpose of Survey to contour surface of, . . 363
" " place of division into two benches of the, ... 392
" colliery, elevations at, ... 395
" mines, Baltimore coal-bed originally opened at, ... 392
" shaft basin, ... 412
" slope, No. 3, in Baltimore bed, ... 392
" " beds worked, ... 368
" tunnel, beds worked, ... 368
" Stanton anticlinal, ... 413
" & Ohio R. R. elevations, ... 127
" " " (Pittsburgh division) elevations, ... 131
Balltown oil pool, production of, ... 18
" " rise and fall of, ... 1
Barnesville, large gas well, ... 83
Barnard, Professor, work of party with, ... 697
Barren coal-measures, description of, ... 177
Barton coal-bed, description of, ... 180

Page.
Basins, anthracite, depths of, ... 285
" and anticlinals, Northern coal-field, ... 398-404
Bast colliery, analysis of coal from, ... 323
Bear Run colliery, analysis of coal and ash from, ... 323
Bear Pen point, dip of rocks near, ... 257
" " capped by Pottsville conglomerate, ... 258
Bear's Head triangulation station, ... 689,705
Beartown triangulation station, ... 694,701
Beaver, Beaver county, ... 41
" creek, kaolin on, ... 599
" county gas wells, ... 4
" Falls gas supply, ... 41
" " change in rocks developed at, ... 11
" Marsh & Co., ... 585
" valley well, history of, ... 37
Beechwood colliery, analysis, coal and ash from, ... 323
Behee's pond anticlinal, ... 416
Bell, I. Lowthian, ... 309
Bellerophon, ... 457
" *nodocarinatus*, ... 457
Belle-Vernon, wells at, ... 41
Bellevue mine, ... 185
Belgian coal-field, ... 319
Bellevue, Lackawanna county, ... 705
Bell magnetic ore mine, ... 566
" tunnel, section, ... 343
Belt line theory, ... 44
" lines and surface indications, ... 70
Beltzhoover borough, ... 163
Belvidere, N. J., line marking glacial epoch at, ... 615
Bennett coal-bed, where mined, ... 368,372
" colliery, operator and beds worked at, ... 368
Bennett's creek anticlinal, ... 417
Berlin, A. P., Survey of Lehigh region by, ... 347
Bernice anthracite and bituminous beds, ... 318
" coal-beds, identity of Lykens valley beds with, ... 472
" coal softer than white ash anthracite, ... 466
" " properties and structure of, ... 471
" " basin, report on, ... 459
" " " no accurate surveys of, ... 462
" " " progress of work in, ... 272
" breaker, ... 466
" mines, State Line and Sullivan R. R. Co., ... 465
" mine map up to February, 1884, ... 465
" and Lykens valley beds, ... 305
" white ash coal, character of, ... 305
Berwick, Luzerne county, line marking glacial epoch at, ... 615
" " " Susquehanna river at, ... 637
Bethel, triangulation station, ... 704
Bethlehem observatory, ... 706
" Reformed church, ... 705

Big Hill, Cornwall, ... 495
" " elevation of, ... 491
Bigley mines, coke produced at, ... 176
Big Tracy coal-bed, analysis, ... 321
Big Rock triangulation station, ... 703
Bismarck, ... 544
Bischof, on deposition of coal, ... 102
" theory of conversion of bituminous to anthracite, ... 319
Bitumen, no vegetable fibre detected in, ... 103
" not found in horizontal strata, ... 103
Bituminous and cannel coal, difference between, ... 114
Black Diamond colliery, elevations, ... 389
" " " operator and beds worked at, ... 368
" " " wash in shaft, ... 644
Blackspot triangulation station, ... 694,702
Blaine, James G., coal not classed as pool No. 3, ... 205
" " property of, ... 211
Blair station, P. V. & C. R. R., ... 159
" Pin Hook anticlinal axis near, ... 160
Blairsville, ... 167
Blewitt, Benjamin, copper ore mined at Cornwall, ... 548
Blue mountain and New York triangulation connected, ... 695
Blue ridges, mention of, ... 283
" section showing structure of, ... 281
Blumenbach, researches on the origin of coal, ... 96
Bly, Tioga county, geographical position of, ... 706
Bore-holes at Nanticoke, positions of, ... 629,633
Bore-hole records withheld from Survey, ... 358
Botryogen found at Cornwall, ... 547
Bowkley coal-bed, where mined, ... 368
Boston colliery, operator and beds worked of, ... 368
" " elevations, ... 381
" Run colliery, analysis of coal and ash from, ... 322
" " " " " coals from, ... 321,323
Bowden, J. H., mining engineer, Susquehanna Coal Co., ... 628
Bowman's mountain, ... 459
Boyd, J. Taylor, on copper ore at Cornwall, ... 549
" " statement by, ... 551
" " superintendent at Cornwall, ... 518
" " mention of, ... 532
Boyd's Hill well, Pittsburgh, ... 5
" " " water delivered by, ... 662
Boyd's opening, coal at, ... 186
Boyer, Jerome L., letter about Cornwall ore, ... 535
Bradford and Allegheny oil-fields, decadence of, ... 1
" district, gas very prolific in, ... 31
" " statistics relative to, ... 15
" " general description of, ... 14
Bradford Fourth oil-sand, geological position of, ... 3
" oil-sand, horizon of, ... 16

Page.
Bradford oil-sand, McKean and Elk cos., drillings below, ... 3
" " not located in Germania wells, ... 94
Brady's Bend or Washington anticlinal, ... 162
" " arch, fall of, ... 49
" " axis, full of water going north-east, ... 49
" " well No. 1, oil and gas struck in, ... 58
Bramwell, Sir Frederick, mention of, ... 309
Brandywine Summit kaolin-bed, Delaware co., ... 593
" " " " decomposition of feldspar bed into, . . 598
" " " quarry near Elam, ... 572
" " " pits, map of, ... 592
" " " works, John Griffen's estate, ... 593,596
" " " " plan of, ... 612
" " Station, P. & B. C. R. R., elevation, ... 582
Branner, J. C., assistant, date of service of, ... 354
" facts on pot-hole, reported by, ... 621
Breckenridge coal, Kentucky, *stigmaria* found in, ... 98
Bridgewater gas-field, prospects of, ... 40
Britton, J. Blodget, analysis of kaolin by, ... 588
Broad run, direction of, ... 574
" limestone, safely taken for formation No. II, ... 576
Brochanite found at Cornwall, ... 547
Brock, Arthur, analysis Cornwall ore, ... 534
Brongniart, researches on origin of coal, ... 98
Brookside colliery, analysis of coal and ash from, ... 322
Brookville, Jefferson co., wells drilled at, ... 35
Brown, J. Benton, surveys by, ... 462
Brown's Saltzburg Works, coke produced at, ... 176
Brown, W. H. & Son, operating Cornell and Werling mine, ... 187
Brownsville, ... 168
Brush ridge, ... 166
Buccinum undatum, ... 117
Buchannon well, deepest in Pennsylvania, ... 7
" " compared with Fagundus well, No. 37, ... 7
Buck mountain coal-bed, analysis of, ... 313,321
Buena Vista, anticlinal near, ... 161
" coal opened N. W. of, ... 198
Buffon, statement as to origin of coal, ... 98
Bull creek axis, full of water going N. E., ... 49
" gas-field, developments in, ... 37
Buried (Wyoming) valley, mine accidents from working into, ... 647
" " areas, colliery workings approaching, . . . 647
" " description of, ... 387,615,627,629
" " north edge of, developments relating to, . . 646
" " page plate showing, ... 638
" " report of Frank A. Hill, ... 637
" " work of ages of erosion, ... 637
" " between Wyoming and West Pittston, . . . 639
Burns gas-well, Butler and Clarion oil-fields, ... 34
Burroughs colliery, operator and beds worked at, ... 368
" " elevations, ... 389

Butler belt, recent developments along, ... 22
" county, Thorn creek pool in, ... 22
Butler county, gas producing rock in, ... 35
" oil-field, sands and rocks developed in, ... 8
" county, pressure of gas in, ... 39
" -Clarion oil-field, description of, ... 21
" and Clarion oil-fields, many extraordinary gas wells in, ... 34
" twp. line marking glacial epoch through, ... 616
Buttonwood creek, ... 639
" shaft, developments at, ... 646
Butzbach's-Buttonwood anticlinal, ... 416
" landing, ... 639
Byssolite, found at Cornwall, ... 547

C.

Calcite, found at Cornwall, ... 547
Callender gap, pot-hole in vicinity of, ... 619
Cambria Iron Co., analysis of gas by chemist of, ... 675
Campbell and Bakewell's mine, ... 218
Campbell's ledge plant bed, ... 490
Canal limestone, occurrence of, ... 445
" " cut in Dorrance shaft, ... 447
"Cannel Anthracite," suggested as a name for bony coal, ... 317
Cannelton, species of plants obtained at, ... 95
Cannonsburg, gas from, ... 38
" gas from Homewood sandstone, ... 38
" gas from Venango-Butler group, ... 38
" field, progress of developments in, ... 40
Canoe creek, Indiana county, Snyder well on, ... 35
Carbonic acid in limestone, determination of, ... 539
Carboniferous age, slate beds, ... 447
" " fossils in limestone beds of, ... 441
" Wilkes Barre fossils, ... 450
Carbon ratio *versus* fuel ratio, ... 302
Cardium edule, found in France, ... 117
Carll, John F., report on oil and gas, ... 1
Carnegie, A., consumption of fuel at Pittsburgh, ... 678
" Murraysville gas pressure, ... 666
Carper ore mine, ... 544
Carroll twp., Washington county, elevations, ... 152
Carr's tunnel, ... 166
Carruther, researches on the origin of coal, ... 99
Cashup, character of oil at, ... 63
Castle Rock, Crum creek, ... 571
Catskill No. IX, in Potter county, ... 93
"Cave-in" at Nanticoke, description of, ... 627
Cemetery anticlinal, description of, ... 411
" " outcrop of Mill creek limestone, along crest of, . . . 447
" basin, description of, ... 410
Central or "green oil" line of development, ... 62
Centralia, Mine Sheet No. IV, ... 343

Centreville district, pipe line to New Castle, ... 35
Cephalopoda, ... 457
Chadd's Ford, (P. & B. C. R. R.,) elevation, ... 563
Chalcedony, at Cornwall, ... 547
Chalcopyrite, at Cornwall, ... 546
Chalybeate springs, from bottom of No. XII, ... 486
Chamberlain, T. C., on ore bearing clays, ... 591
Chambers, J. C., record of wells received from, ... 63
Chamber of Commerce, Pittsburgh, report on gas by, ... 665
Chance, H. M., fuel value of natural gas, ... 675
" value of coals to consumers, ... 306
" calculation of gas quantities, ... 668
Charlestown mine, ... 198
Chartiers R. R., elevations along, ... 139
" twp., Allegheny county, elevations, ... 143
Chauncey colliery, operator and beds worked at, ... 368
Cheat river, ... 166
Checker coal-bed, Pine Ridge and Laurel Run collieries, ... 392
" " where mined, ... 368,372
Chemical composition of Cornwall ore, ... 531
" " of kaolin, ... 565
" evidence as to origin of coal, ... 100
Chemistry of mineral waters, Dr. Hunt, ... 589
Chemung, No. VIII, lifted by Savage Mountain anticlinal, ... 227
Cherry Grove district, oil production in, ... 18
Cherry run, gas spot located at, ... 35
Chestnut Hill Iron Co., use of Cornwall ore by, ... 535
Chester valley limestone, ... 575
Chickies Iron Co., use of Cornwall ore by, ... 535
Chonetes Millepunctata, ... 440,452
Chrisman, F., coal opening, ... 486
Chrisman coal-bed, section, ... 487
Chrysocolla at Cornwall, ... 547
Church coal-bed, where mined, ... 372
Clera mine, description of, ... 197
Claghorn, Clarence R., assistant, ... 354
" " coal specimens obtained by, ... 470
" " Bernice mine map examined by, ... 478
" " assistant on Bernice survey, ... 463
Clarendon pool, ... 17
Clapp well, ... 7
" stra'a encountered in, ... 17
Clarendon and Warren, gas piped to, ... 33
Clarion belt, gas in wells east of, ... 35
" county, Cogley run oil-pool in, ... 1
" oil-rocks, Warren and Forest wells, ... 17
" sands in Forest co., ... 17
Clarksville, ... 18
Classification and composition of Pa. anthracites, ... 300
Clay for market, preparation of, ... 611

Page.
Clay remaining on Johns' and Griffin's farms, ... 603
" bed in Delaware and Chester co's, ... 594
" beds of New Jersey, Delaware, Maryland, and Virginia, ... 583
" mining, Brandywine Summit clay-bed, ... 606
" vein at Eicher's pit, ... 200
Clear Spring shaft, wash out in, ... 640
Coal, hypothesis of formation of, ... 104
" in England composed of spores, ... 98
" objections stated as to the vegetable origin of, ... 97
" objections answered as to the vegetable origin of, ... 97
" plate showing the internal vegetable structure of, ... 122
" problem of formation not fully solved, ... 101
" questions in considering the formation of, ... 101
" the vegetable origin of, ... 95
" the Vail hypothesis of origin of, ... 103
Coal-basins in Eastern Middle Coal Field, ... 347
Coal-beds, average thickness on Mine Sheet, No. VIII, ... 391
" conventionals used on the anthracite sheets, ... 367
" identity near Ashley and Wilkes Barre, ... 381
" on Kingston Mine Sheet, No. VII, ... 385
" names differing on Mine Sheet, No. VII, ... 387
" those workable under the Bennett bed on Mine Sheet VI, . . 385
" uncertain nomenclature of, ... 366
" variability in different areas, ... 372
Coal-bed A, (Bernice basin,) 466
" " analysis, ... 469
" " change in carbon ratio, ... 471
" " at Heiss opening, ... 467
" " unworkable, in Bernice basin, ... 469
" in Pottsville conglomerate, ... 393
" B, Bernice basin, ... 471,474
" " commercial value, ... 466
" " Bernice basin, mined by S. L. & S. R. R. Co., ... 463,465
" " Bernice basin, section of, ... 474
Coal Bluff mines, ... 159
Coal Flora, reports on the, ... 120
" gas, variation in fuel value of, ... 676
Coals, grouping into ten classes, ... 303
Coal measures of Anthracite Region, limestone beds rare in, ... 438
" " on highest summits Loyalsock and Mehoopany Fields, . . . 461
" vegetation, interrupted, ... 120
Cochran, A. B., topographical map by, ... 345
Cogley Run oil-pool, Clarion county, opening of, ... 1
" " oil from Venango-Butler sand, ... 22
" well, ... 25
Coleman, W. & R. W., copper sold from Cornwall by, ... 549
" R. W. & W. and R. & G. D., owners of Cornwall mine, ... 550
Coleraine, Nos. 1 and 2, collieries, analysis, Mammoth bed, ... 314
" " " " Wharton bed, ... 314
Colket colliery, analysis of coal and ash from, ... 323
Collieries on Northern Coal-field mine sheets, ... 368

Columnar structure of coal measures in Northern Coal Field, ... 421,423
Commissioners, Board of, ... 347
Composition of Bernice coal, ... 476
" of Pennsylvania anthracites, ... 307
Compressed air locomotive, ... 216
Compressor at Cornwall, ... 558
Confusion in identification of oil-sands, ... 67
Connellsville sandstone, ... 179,212
Conglomerate, oil-well wild catting caused by, ... 44
Congress, appropriation for triangulation by, ... 693
Conner colliery, analysis of coal and ash from, ... 322
Conodoguinet creek, slates exposed along, ... 541
Conyngham anticlinal, ... 411
" colliery, operator and beds worked, ... 368
" " elevations, ... 395
" shaft, limestone outcrop near, ... 447
" " section, ... 423
" " synclinal, ... 412
Cook, Professor G. H., clay beds described by, ... 583
Cooper coal-bed, called Four-Foot east of "Harry E." colliery, ... 385
" " rapid thinning of, ... 385
" " Northern Coal-field, ... 368,372
" district, ice in oil-wells, ... 38
" oil pool, rise and fall of, ... 1
" T., notice of mineral by, ... 655
" tract, oil production on, ... 16
Copper in Cornwall ore, ... 548
" Middle Hill, Cornwall, ... 512
Cornell and Werling mine, ... 187
" " section of coal-beds at, ... 188
Cornen gas pool, strong and lasting wells in, ... 33
Cornwall ore, ... 504
" " cost of mining, ... 552
" " difficulty in working the, ... 585
" " mining of, ... 549
" " part of sedimentary formation of Lebanon limestone valley, 539
" " regular stratified formation, ... 504
" " thickness of, ... 505
" Ore Bank Co., grade of ore mined by, ... 534
" ore mine, cross sections of, ... 506
" " Lebanon county, report on, ... 491
" " map showing location of, ... 492
" and Mt. Hope R. R., ... 494,525
" slates, lime slates spoken of as, ... 540
Coulterville pit, Pittsburgh bed opened, ... 197
Courtney station, P. V. & C. R. R., ... 168
Covelite, found at Cornwall, ... 546
Coxe, Eckley B., assistance afforded Survey by, ... 352
Coxton branch, L. V. R. R., bore-hole north of, ... 641
Craft pit, ... 164
Cranberry, Venango-Butler group south-west of, ... 4

Page.
Cranberry twp., gas found in, 4
Crawford's clay, used for fire-brick, 572
" kaolin works, 571
" Delaware county, kaolin at, 573
Creighton plate glass works, 38
Cresson, Dr. Charles M., analyses of anthracite coal and ash by, 322
Crinoidal limestone, 180
" " key to geological structure of oil-regions, 4
Cross creek twp., Washington county, gas in wells sunk in, 26
Crossland coal, 185
Cuba, gas from Allegheny gas district piped to, 31
Cuprite, found at Cornwall, 546
Cyperaceœ, 649

D.

Daddow's coal opening, 487
Daggert's lower coal pit, 199
" upper coal pit, 199
Daubreé, cause of rock metamorphism, 319
Dauphin triangulation station, 695, 705
Davidson, G., results of angle measurements on U. S. C. & G. S., 692
Dawson, Sir James W., origin of coal, 99
" " vegetable structure of coal, 123
de Bomarre, Valmont, belief as to origin of coal, 96
Debray, M. H., section of peat bog, 116
Delamater gas well, Butler and Clarion oil fields, 34
Delano mine sheet, (No. I,) area of, 339
" " " beds worked on, 338
Delaware, feldspar rock quarries, 572
" water gap, Kittatinny mountain, 282
" and Chester counties, streams in, 571
" " " kaolin deposits, general considerations of, 571
" " county rocks, kaolinization of, 577
" & Hudson C. Co., first shipment of coal by, 278
" " " collieries, elevations at, 381
" Lack. & West. R. R. Co., bore-hole records withheld by, 358
Delesse, analysis of albite, 586
Denmark governmental surveys 692
Departement du Nord, peat dug in, 116
Derrick hand-book, statistics of Bradford oil district, 15
Dewey, Prof. F. P., plan for testing coals, 309
Diamond colliery, operator and beds worked, 368
" shaft colliery, elevations at, 394
Dillsburg magnetic ore mines, 569
" " " beds, 569
" " " confined to Triassic formation, 569
d'Invilliers, E. V., report on Cornwall ore mines, 491
" C. S., section at Loop Run opening, 259
Discina convexa, 452
Dismal swamp, peat deposits, 106

Page.

Dodson colliery, operator and beds worked at, ... 368
" " elevations at, ... 380
Doolittle, C. L., location of Wilkes Barre, ... 361
Döppler, paper read before Vienna Academy, ... 652
"Dopplerite" from Scranton, ... 615
Dopplerite not yet discovered in America, ... 654
Dorrance colliery, operator and beds worked, ... 368
" " elevations, ... 396
" shaft, Canal limestone bed cut in, ... 447
" " Joe Gibbs' coal-bed cut in, ... 445
Downthrow fault, Cornwall ore-mine, ... 529
Draper colliery, analysis of Mammoth and Primrose coals, ... 315
Dravos country pit, Pittsburgh coal-bed opened, ... 197
Dresser, S. R., opinion on gas pressure, ... 663
Drifton basin, depths of points in, ... 285
" Mine Sheet No. I, coal-beds worked on, ... 349
" " " " sections at Drifton and Lattimer, ... 349
" and Hazleton, maps restricted to vicinity, ... 347
Drills, Ingersoll rock, used at Cornwall, ... 557
Drummond lake, Virginia, formation of bottom, ... 106
Dry run mine, elevation Pittsburgh coal-bed, ... 218
DuBarry, J. N., Tipton report furnished by, ... 265
Duncan, Cornell and Werling, ... 187
Duncannon, Perry county, Pocono coal, ... 254
Dundee shaft, fossils from, ... 448
" " high coal measures cut in, ... 373
Dunkard creek oil district, ... 2E
" twp., Greene co., elevations, ... 154
Dunningsville, ... 165
Durham and Reading hills, triangulation stations on, ... 693

E.

Eagle Hill colliery, analysis of coal and ash from, ... 323
Eagle Nest mine, ... 196
East Bethlehem twp , Washington co., elevations, ... 153
East Boston colliery, elevations, ... 399
" " operator and beds worked at, ... 369
" " Ross and Red Ash beds cut at, ... 396
East Franklin colliery, analysis of coal and ash from, ... 323
East Pike run twp., Washington co., elevations, ... 152
Eastern Middle Coal-field Atlas, ... 347
" " extent of, ... 275
" " report on, ... 349
" " sections in, ... 291
" " structure of, ... 284
" " survey of, ... 347
" " known as Upper Lehigh region, ... 347
Eaton colliery, pot-holes at, ... 617
" Knob, ... 459
Ebervale, No. 2, colliery, ... 314

Page.
Edgemont, ... 571
Edmundson mine, ... 183
Edinboro', geographical position of, ... 706
Eichers' pit, ... 199
Elam, Concord twp., Delaware co., ... 572
Elevations, Allegheny co., ... 142
" " railroad, ... 140
" Anthracite regions, ... 281
" Bernice coal basin, ... 464
" B. & O. R. R., accuracy of, ... 127
" " Pittsburgh division, ... 131
" " Wheeling division, ... 137
" Chartiers railroad, ... 139
" P. & C. R. R., Fayette branch, ... 133
" " Mt. Pleasant branch, ... 133
" Pittsburgh, Cincinnati & St. Louis R. R., ... 138
" Pittsburgh, McKeesport & Youghiogheny R. R., ... 134
" Pennsylvania R. R., ... 128
" P. R. R., Monongahela division, ... 135
" South-West Pennsylvania R. R., ... 129
" West Penn R. R., ... 141
" Youghiogheny R. R., ... 131
" Fayette co., ... 156
" George twp., Fayette co., ... 156
" Jefferson twp., " 156
" Luzerne twp., " 156
" Nicholson twp., " 157
" Spring Hill twp., " 158
" Washington twp., " 156
" Greene co., ... 153
" Monongahela twp., Greene co., ... 153
" Washington co., ... 151
" Allen twp., Washington co., ... 152
" Carroll " " " 152
" East Bethlehem twp., Washington co., ... 153
" " Pike run " " " 152
" Nottingham " " " 151
" Peters " " " 151
" Union " " " 150
" Westmoreland co., ... 154
" North Huntingdon twp., Westmoreland co., ... 155
" Rostraver " " " 154
" Sewickley " " " 155
" on Mine Sheet, No. VI, N. C. F., ... 383
" " " " VIII, " 393
" pools in Monongahela slackwater, ... 136
" in Pittsburgh, ... 139
Eleven-foot coal-bed, Maltby colliery, ... 385
Elizabeth, Allegheny co., river mines near, ... 169
" twp., " 127,187
" " " elevations, ... 148

Elk co., oil-sand, . . . 16
" mountain, Susquehanna co., . . . 461
" and McKean cos., drillings below Bradford oil sand, . . . 3
" co. oil-wells, . . . 15
" triangulation station, . . . 697,705
Ellangowan colliery, analysis of coal from, . . . 321
" and Indian Ridge collieries, section of coal measures at, . . . 341
Ellerslie, fire-brick works near, . . . 247
" James Gardener, fire-brick works at, . . . 247
Elmwood colliery, analysis of coal and ash from, . . . 322
Emerged bogs, formation of, . . . 113
Emery, Titus S., information from, . . . 259
" " samples selected by, . . . 264
Emlenton and Scrub Grass, oil-belt between, . . . 73
Empire, No. 2, colliery, elevations, . . . 392
" " " operator and beds worked at, . . . 369
Empire, No. 4, colliery, elevations, . . . 394
" " " operator and beds worked at, . . . 369
" " " section inside tunnel, . . . 431
" basin, . . . 413
Engineering and Mining Journal, Nanticoke accident described, . . . 627
" " " prices of gas quoted from, . . . 678
" " " statement on Murraysville gas wells, . . . 666
Enterprise colliery, elevations, . . . 389
" " operator and beds worked at, . . . 369
" " workings of, . . . 639
Erie, geographical position of, . . . 706
" gas-wells, . . . 83
Ernhout & Taylor well, record of, . . . 663
Espy run anticlinals, . . . 419
Eumicrotis Hawni, . . . 455
Exeter shaft, depth of cribbing in, . . . 640

F.

Fagundus, character of oil at, . . . 63
" well No. 37, depth of, . . . 7
" " " slates and shales in, . . . 17
Fairview gas well, Butler and Clarion oil-fields, . . . 34
Fairfield, G. A., triangulation by, . . . 698
Farley and Wilson oil well, lime-sand in, . . . 222
" " " " " limestone in, . . . 222
Fault at Cornwall, . . . 496
Fayette anticlinal, . . . 166
" branch, P. & C. R. R., elevations on, . . . 133
" county, elevations, . . . 156
Fechtig, Dr., Wellersburg oil-well record, . . . 229
Feldspar bed, kaolin derived from decomposition of, . . . 598
" into kaolin, rate of change unknown, . . . 583
" and kaolin beds, Chester co., strike of, . . . 576
" " " belts, Delaware co., strike of, . . . 576

Page.
Fell, Judge, anthracite first used in house of, ... 278
Ferriferous limestone, key to oil-region geology, ... 4
Fetterman oil-well, large gas producer, ... 41
Finley, C. B., ... 259
Finleyville, ... 164
Fire Island, triangulation base line, ... 688
First geological survey, ... 279
" " " numbers, ... 287
" report anthracite survey, reference to, ... 269, 291
" " " " analysis, McCreath, reference to, ... 324
" " " " analyses in, ... 317
Fish island, channel cut in river at, ... 646
Fish-pot limestone horizon, ... 173
" " " Pierce's fork, Howell's creek, ... 194
Five-foot coal bed, location of, ... 387
" " " " where mined, ... 368, 372
First oil sand, Butler co., gas from, ... 35
Fish island, bend of Susquehanna river, ... 639
First oil sand, oil from, ... 63
" " " traced, Oil creek to Bullion, ... 8
" and Second sands, no oil produced along center of belt, ... 63
" Second, and Third sands of Oil creek, ... 28
Finney coal-bed, ... 204
Flatwood P. O., ... 166
Flick, W. J., ... 354
Flora of coal period, plants composing the, ... 118
Foliated micaceous hematite, Cornwall, ... 546
Ford, S. A., report on theoretical value of gas by, ... 673
Ford & Nelson, gas developments by, ... 37
Forest and Warren cos., oil pools in, ... 1
Forkston, Mehoopany coal-field, ... 486
Formations of Middle and Western Penn., ... 119
Forney, Charles B., ... 551
" " " cost of ore and iron at Cornwall, ... 554
Forty Fort colliery, buried valley at, ... 643
" " " elevations at, ... 390
" " " operator and beds worked at, ... 369
Forward twp., Allegheny co., description of, ... 127, 204
" " section in, ... 205
" " no railroads in, ... 205
" " elevations in, ... 148
Fossils, Wyoming Valley limestone-beds, ... 450
" from Dundee shaft, ... 448
" Wilkes Barre, list of, ... 451
Foster, Prof. William, experiments on composition of coal, ... 308
Foster, William, limestone outcrop reported by, ... 258, 259
Four foot coal-bed, where mined, ... 368, 372
" " " Wyoming colliery, ... 392
Franklin colliery, elevations at, ... 383
" " operator and beds worked, ... 369
" overturn, ... 400

Franklin slope anticlinal, ... 414
Frazer, Dr. Persifor, coal classification of, ... 301
" " " dips in Chester co., recorded by, ... 577
" " " explanation of gentle dips in feldspathic rocks, . . . 577
Free burning white ash coal, definition by Joseph S. Harris, ... 304
Freeport, ... 167
" gas deposits, ... 36
Friendship, gas from Allegheny district piped to, ... 31
Früh, researches on the origin of coal, ... 99
Fuel ratio *versus* carbon ratio, ... 302
" " explanation of, ... 301
" value of coals, tests proposed, ... 309
" " " Penna., anthracites, differences in, ... 308
Fuller Coal Company's property, bore-hole on, ... 641
" colliery, crevice cut in inside slope, ... 642
" " operator and beds worked at, ... 369
" " elevations at, ... 390
Furnace creek, elevation, ... 494
" " location of trap along, ... 490
" colliery, analyses coal and ash from, ... 322
Furnaces, list of, within twenty miles of Cornwall, ... 558

G.

Gabby oil well, Washington county, ... 26
" " Gantz sand in, ... 27
Gabel iron mines, Boyertown, "horses" of rock at, ... 511
Gantz oil-well, Washington county, date of oil strike, ... 26
" " " " " limestone in, ... 222
" " sand, struck in Gabby well, ... 27
Gardner's three-cylinder engine, ... 245
Gardner pit, coal opened at, ... 214
Gas City and East Sandy, waste of gas at, ... 34
" from old peat deposits, ... 119
" in Pennsylvania, found in sand-beds, ... 51
" pressure at well, ... 665
" sand in Pittsburgh wells, ... 10
" " position in Thorn creek district, ... 8
" " Thorn creek district, identity of, ... 8
" stock, exhaustion of, ... 671
" "streaks" common throughout oil-regions, ... 30
" to oil, relation of, ... 30
" waste of, ... 667
" wells, greatest known pressure in, ... 663
" works (Wilkes Barre) basin, ... 411
Gates drift, bed opened, ... 262
" section at, ... 262
Gaylord colliery, operator and beds worked at, ... 369
" " elevations at, ... 390
Genth, Dr. F. A. analysis, kaolin, ... 568
" " trap rock, ... 497

Genth, Dr. F. A., crystals of magnetic iron found in brown hematite ore, . 515
" description Cornwall minerals, ... 546,548
" ores described in T[4], p. 392, ... 531
Geography of anthracite region, ... 275
Geology of petroleum, ... 54
" " recapitulation, ... 75
Geological facts (in oil regions) to be noted, ... 81
" Survey, purposes as to special examinations of coal-beds, . . . 366
George's twp., Fayette county, elevations in, ... 156
Germania Oil Co.'s test wells, location of, ... 84
" " wells drilled by, ... 88
Geyser well, Sargeant pool, Report R., p. 244, ... 31
Gies, France, fragments of coal plants found near, ... 95
Gilberton colliery, analyses, coal and ash, ... 315,322
Girard College, Philadelphia, position of, ... 705
" colliery, analysis of coal and ash from, ... 322
Girardville Mine Sheet, No. III, area of, ... 341
" " " coal-beds worked on, ... 342
" " " description of, ... 341
Girtie's run, ... 163
Glacial epoch, description of line marking, ... 615
" geology studied by Survey, ... 617
Gladden's run, section on, ... 229
Glendower colliery, analyses of coal and ash from, ... 323
Glen Mills gneiss belt, line of axis, ... 571
" Chester creek, reference to, ... 571
Godfrey & Clark's paper-mill, ... 38
Gœppert, cellular structure of coal seen in ash, ... 123
Golding, Mr., system of clay mining at Hockessin, ... 609
Golding's old clay mill, ... 598
Gordon oil well, Washington county, oil from, ... 11
" " " " production, ... 26
Gore Brothers, anthracite first used in Pennsylvania by, ... 277
Gormley's country pit, ... 164
Governor of Pennsylvania, request in regard to triangulation of State, . 698
Governor Dick triangulation station, ... 695,701
Graff, Bennett & Co., gas developments by, ... 37
Grammysia (Sp.?) 442,457
Grant & Horton's tannery, Ridgway, well near, ... 32
Grape ridge, ... 166
Grapeville, ... 166
" dry-gas, analysis of, ... 677
Grassy hill, Cornwall, description, ... 513
" elevation of, ... 491
" dyke, ... 501
Great limestone, near Round Hill church, ... 194
" Britain, results of angle measurements in, ... 692
Greene county, elevations in, ... 153
Green Oak mine, same as Eagle Nest mine, ... 196
Greensburg basin, same as Lisbon synclinal, ... 168
Greenwich meridian used by Coast and Geodetic Survey, ... 682,707

Page.
Greenwood colliery, Tamaqua, coal from, ... 291
Griffin farm, Delaware county, explorations on, ... 594
" limestone-beds not found on, ... 602
" lands comprising the, ... 606
Griffith, William, assistant, Bernice survey, ... 463
Group of oil sands, the, ... 64
Grubb, Edw. B. & Clement, Cornwall mines, ... 550
Grubb's new bore-hole, wash at, ... 494, 528
Guffey's station, ... 168
Gumbel, researches on origin of coal, ... 99
Gumpert, Hewey & Co., Bellevue mine, ... 185
Gypsum, found at Cornwall, ... 548

H.

Hacklebarney tunnel, thickness of strata, ... 294
Hackley, Col. C. B., pot-hole on land of, ... 617
Hague or Sheffield well, remarkable history of, ... 32
" " " Sheffield gas-pool discovered by, ... 32
" well sand, well at Barnesville in, ... 33
Hägnetswyll, Switzerland, peat from, ... 654
Halberstadt, Baird, work in Northern coal-field, ... 354
" " assistant on Bernice survey, ... 463
Hall, Prof. James, section near Wellersburg, ... 229
Hanover government survey, results of angle measurement by Gauss, . . 692
Hanover Green anticlinals, ... 415
" "Hogback," 416
Harden, E. B., Sullivan county survey by, ... 486
" " map of Bernice basin by, ... 463
" " model of Cornwall mines by, ... 491
" " report on Wellersburg fire-clay by, ... 239
Harden, O. B., field work in Eastern Middle Field, ... 347
" " assistant in Northern Field, ... 354
" E. & O. B., model of Western Middle Field by, ... 340
Harman's summit, Pittsburgh bed in, ... 236
Harris, Joseph S., defines characteristics of coals, ... 304
" Stephen and Joseph S., map made by, ... 345
Harrisburg, capitol, position of, ... 706
Harrison, Potter county, ... 706
Harrisville district, gas leases in, ... 35
Hartley, F. W., experiments with coal-gas, ... 677
"Harry E." colliery, bottom bench Baltimore bed worked, ... 385
" " operator and beds worked at, ... 369
" " elevations, ... 390
" shaft, anticlinal in slope at, ... 405
" " wash in, ... 643
Harrison township, Potter county, oil-well in, ... 83
Hartford, No. 6, colliery, operator and beds worked at, ... 369
Hartz mountain, boulders covered with moss, ... 113
Harvey O'Neill mine, ... 211
Harvey's run, shaft for kaolin on, ... 599
" gas well, history, ... 36

Hammond colliery, analysis of coal and ash from, ... 322, 323
Hanover bore-hole, section, ... 376, 426
" No. 17, colliery, operator and bed worked at, ... 369
" " " elevations, ... 376
Hard white ash coal, J. S. Harris' definition, ... 304
Haupt, Prof. L. M., resignation from triangulation survey, ... 694
" " triangulation in Pennsylvania by, ... 693
triangulation station, geographical position of, ... 699, 703
er, No. 1, oil well, Murraysville district, ... 37
basin, depth of points in, ... 285
Mine Sheet No. II, coal-beds worked on, ... 350
" " topographical survey on, ... 351
, coal quarried in vicinity, ... 297
oil-well drilled at, ... 33
, Prof. Angelo, report on Wilkes Barre fossils, ... 441, 450
" " drawings of fossils made under supervision of, . . . 443
ening, coal-bed A opened at, ... 467
on's, J. R., upper pit section, ... 199
" lower pit section, ... 199
nticlinal, ... 407
asin, ... 407
verturn, ... 400
olliery, operator and beds worked at, ... 369
" elevations, ... 388
" workings of, ... 639
nd Wyoming fault, ... 406
mill oil-pool, ... 1
district, gas from Homewood sandstone, ... 33
" gas from Venango-Butler group, ... 35
" gas supplying Pittsburgh from, ... 36
ink A., placed in charge Northern coal-field, ... 353, 354
" Dorrance shaft section, ... 445
" location of fossiliferous slate in Dundee shaft by, ... 443
" reconnoissance of Mehoopany coal-field made by, ... 486
" notes on Mehoopany coal-field by, ... 486
" description of buried Wyoming Valley, ... 687
" mineral found by, ... 648
, Washington county, ... 160
mine, level of coal at, ... 160
colliery, operator and bed worked at, ... 369
" elevations, ... 397
coal-bed, place of, Mine Sheet No. VII, ... 387
coal-bed or H., where mined, ... 366, 372
vein colliery, operator and bed worked at, ... 369
vein shaft, coals cut in, ... 391
and Mills coal-beds, workings at Nanticoke in, ... 629
o' and Rose Valley Mills, schists of Delaware county at, ... 571
n and Waldmarsland, peat-bogs between, ... 109
of anthracite region, ... 277
mining at Cornwall, ... 568

Page.
Hite Gas Company, ... 667
" " wasting gas from Bull creek field, ... 38
Hockessin clay, analysis of, ... 587
Hodgson's coal pit, ... 164
Hollenback air shaft anticlinal, ... 412
" shaft, analysis Baltimore bed, ... 314
" cemetery, limestone outcrops near, ... 445
Hollenback colliery, operator and bed worked, ... 369
" " elevations at, ... 394, 397
" dam, limestone outcrop near, ... 443
Homewood district, gas to Pittsburgh from, ... 38
" gas from Venango-Butler group, ... 38.
" sandstone in McGuigan well, ... 40
" " gas from, ... 38
Honey Pot tunnel anticlinal, ... 419
Hoosac tunnel, demoralized rock from, ... 578
Hopkins, James H., coal land owned by, ... 195
Horner & Roberts mine, ... 206-211
" " classification of coal, ... 205
Horse Shoe Chain, precision of work in, ... 694
Howell, W. G., coal land owned by, ... 195
Howellville, ... 571
Hull, E., memoir on peat-bogs, ... 120
"Hundred-Foot Rock," Thorn Creek oil district, ... 8
" " same as Butler First-sand, ... 8
Hunt's law of relative gravity, ... 585
Hunt, Dr. T. Sterry, Hoosac tunnel rock described, ... 578
" " "chemical essays," 590
Hunter mine, ... 183
Hutchison coal-bed, where mined, ... 370
Hutton, cellular structure of coal, ... 123
Hyde Park, geographical position of, ... 705
Hydrocuprite, found at Cornwall, ... 546

I.

I, Kidney or Bowkley coal-bed, where mined, ... 368
Idlewood hotel, ... 164
Immerged bogs, growth of, ... 113
Indiana axis, ... 167
Indian Ridge colliery, analysis of coal and ash, ... 321, 322
Ingham, Dr. Charles F., fossils collected by, ... 439
Iron ore mines, Lebanon co., report on, ... 491
Iron pyrite, found at Cornwall, ... 546
Irwin basin, ... 168
Irwin's station, P. R. R., ... 168

J.

J, Seven-Foot or Abbott coal-bed, where mined, ... 368
Jack's run, erosion by, ... 161

Jackson ai
" d
" e
" n
"
"
" a
Jamestow
Jeddo, No
Jefferson t
"
Joe Gibbs'
"
Johns, H. .
"
"
"
" far
" "
Jones, Edv
" J. I
" Joh
" Sim
" & L
Johnson, I
Jussieu, op

K, coal-be
Kada, Teii
Kane City,
Kaolin, am
" on
" use
" be
" "
" cla
" "
Kaolin dep
" Che
" Lan
Kennel's n
Kennett Sq
Kennet's n
Kent, Will
Kent islanc
Keyes & Ca
Kidney coa
Kingston c
" N
" co

Page.

Kingston flats, alluvial drift on . . . 387

" Mine Sheet No VII, description of, . . . 384

" " " " " coal beds mined on, . . . 384

" No. 3 shaft, section of, . . . 432

Kinzua oil-pool, Warren co., opening of, . . . 1

Kittanning, gas well near, . . . 36

" mountain, area of maximum disturbance, . . . 283

" " boldest topographical feature in State, . . . 282

Klaproth, analysis of peat material by, . . . 117

Knickerbocker colliery, analysis of coal and ash, . . . 322

Knight shaft, wash in, . . . 640

Knob triangulation station, geographical position, . . . 697, 705

Kohinoor colliery, analysis of coal from, . . . 315

Kramer & Hart, Laurel Run coal bank, . . . 263

Kuntze, Dr. Otto, opinion on formation of coal, . . . 104

L.

Labradorite, in feldspar rocks, . . . 585

" Vanarsdale quarry, analysis. . . . 586

Lac d'Etaillères, extensive peat bog, valley of the Brévine, . . . 107

Lackawanna river, discharge of, . . . 623

Lackawannock mountain at Pittston, . . . 637

Lake Ganoga, Sullivan co., reference to, . . . 488

Lake Shore Gas Coal Co., operating Ciera mine, . . . 197

" " gas obtained along, . . . 33

Lancaster county clay, analysis of, . . . 587

Lance colliery, operator and beds worked, . . . 370

" " elevations at, . . . 380

Lake Survey, results of angle measurements on, . . . 692

" " triangulation of, . . . 698

Lancaster prison tower, geographical position of, . . . 705

Lance coal-bed, where mined, . . . 368

Lansford R. R. tunnel, strata in, . . . 295

Lardintown, Butler co., Brady's Bend arch at, . . . 49

" " " gas deposits near, . . . 36

Latitude and longitude, methods of determining, . . . 687

" " " shape of the earth in consideration of, . . . 700

Laurel run colliery, operator and beds worked, . . . 370

" " " elevations at, . . . 396

" " " coal-bed under Lower Baltimore bed, . . . 392

Laurel run coal-bank, Kramer & Hart, examined by Franklin Platt, . . 263

Laurentian gneiss area, Delaware co., . . . 571

Lava, great upburst at Cornwall, . . . 503

Lawrence Myer's tract, bore hole on, . . . 644

Layton station, . . . 167

Lebanon city quarries, fossils from, . . . 545

" co., Cornwall mines on southern border of, . . . 491

LeConte, Joseph, observations on the decay of feldspathic pebbles, . . . 580

Leechburg, gas deposits near, . . . 36

" horizons furnishing gas at, . . . 10

" synclinal, . . . 165

Lehigh basin, (Lower,) extent of, ... 275
" Coal Mine Company, first organization for mining anthracite coal, 277
" " Nav. Co., regular shipments to market first made by, ... 278
" " " " collieries, analysis of coals, ... 315
" " " " authority for section in Panther creek basin, . . 327
" " " " colliery No. 9, average thickness of Mammoth bed in, 290
" red ash coal, not defined, in J. S. Harris' report, ... 305
" & Wilkes Barre Coal Co's. workings, map by G. Morris, ... 353
Lehigh region, facilities afforded survey in, ... 351
" " importance of results of survey work in, ... 352
" " analysis of coals from, ... 310
" Valley Coal Co., bore hole records withheld by, ... 358
" " R. R. at Wilkes Barre, limestone outcrop on, ... 443
" " " Co., topographical map in W. M. C. F. made for, ... 345
" " " " lease of State Line & Sullivan R. R. by, ... 462
" " triangulation begun in east end of, ... 698
Lehman, A. E., model of Cornwall ore territory by, ... 491,495
" George M., Assistant in Northern field, ... 354
" " " surveys in Delaware co., ... 594
Lenni, Delaware co., ... 572
Lesley, J. P., coal-beds and fire-clays of Wellersburg basin, ... 227
" Delaware and Chester county kaolin deposits, ... 571
" Survey work placed in charge of C. A. Ashburner, ... 354
" importance of Wilkes Barre fossils recognized, . . . 439
" lime-water an agent of decomposition, feldspar into kaolin, . 602
" names of formations suggested, ... 268
" notes on the origin of coal, ... 121
" notes on utility of Profs. Linn and Linton's investigations, . 225
" oxidation of coal-beds of anthracite and bituminous basins, . 319
" paper on natural gas of Pennsylvania, ... 657
" plane of decomposition of feldspar bed, ... 600
" report on Tipton run coal-beds, ... 250
" report on Cornwall iron ore, ... 491
" responsible for theory of downthrow fault at Cornwall, . . 496
" section on Towanda mountain, ... 490
" suggestions as to origin of feldspar, ... 599
" suggestion as to origin of pot-hole, ... 624
" thickness of ice in Ice Age in Wyoming-Lackawanna Valley, 615
" variable thickness of conglomerate, ... 289
Lesquereux, Leo, paper on vegetable origin of coal, ... 95
" Survey reports embody life-long observations of, . . . 123
Levels furnished by J. Wainright, ... 155
" miscellaneous, Pittsburgh coal-region, ... 128
Lewis, F. H., Pocono coal-beds cut in Sideling Hill tunnel, ... 254
" Henry Carvill, description of substance resembling dopplerite, 615, 647
Lignite in Red and Mississippi rivers, ... 102
Limestone beds, report on the Wyoming Valley, ... 437
" belts, Chester county, ... 576
" stratum cut in National kaolin pit, ... 601
Limonite beds along South mountains, ... 579
Lincoln twp., Allegheny county, ... 127

" elevations, . . . 146
Lippincott triangulation station, . . . 697
Lisbon synclinal, . . . 162
Litchfield, geographical position of, . . . 706
Little Washington oil field, Washington county, . . . 26
Littorina rudis, . . . 117
Locust Mtn. Coal & Iron Co., map of property, . . . 345
" Mtn. gap, Pottsville conglomerate in, . . . 268
" Spring colliery, analysis of coal and ash, . . . 321,323
Lodgment coal-bed, where mined, . . . 371
Londonderry triangulation station, geographical position, . . . 701
Lone Tree, geographical position of, . . . 705
Long farm, . . . 544
" run, erosion by, . . . 161
Loop run drift, description of, . . . 259
" " coal shipped by P. R. R., . . . 265
" " fuel value of coal, . . . 265
" " sections, . . . 259,261
Lorberry red ash, Joseph S. Harris' definition, . . . 305
Lovedale, . . . 191
" mine, description of, . . . 191
" " section, Pittsburgh coal, . . . 198
Lower Baltimore (Bennett) coal-bed, thickness, . . . 392
" " " " where mined, . . . 368,372
" Barren Measures, variable thickness, . . . 6
" " " Beaver county limestones, . . . 437
" Productive Coal Measure limestones, . . . 437
Loyalsock coal-field, . . . 461
" " structure, . . . 284
" white ash coal, not referred to in J. S. Harris' report, . . . 305
" and Mehoopany coal-fields, . . . 276,459
" " " " or Western Northern, . . . 459
Lucerne, Switzerland, pot-holes at, . . . 634
Lutraria compressa, . . . 117
Luzerne county, Sturdevant's map of, . . . 382
" twp., Fayette county, elevations, . . . 156
Lykens Valley coal-beds, . . . 472
" " red ash coal, definition of, . . . 305
" " physical characteristics, . . . 305
Lyman, Benj. Smith, . . . 354
Lynch & Robinson mine, . . . 188
Lyons run gas well pipe line, . . . 38

M.

Macfarlane, James, opinion on value of Wellersburg coal, . . . 238
Macrocheilus primigenius, . . . 446,457
Macrodon obsoletus, . . . 456
Maffet colliery, operator and beds worked, . . . 370
Magnetic variation, determination at Wilkes Barre, . . . 361

Page.

Mahanoy basin, elevations of points in the, ... 285
" city area on Mine Sheet No. I, ... 339
" " colliery, analysis of coal and ash from, ... 321,323
" " on Mine Sheet No. I, ... 338
" and Shamokin coal-field, extent of, ... 275
Mahoning sandstone, bottom of Barren Measures, ... 178
Main street, Wilkes Barre, outcrops Mill Creek limestone on, ... 447
Malachite, found at Cornwall, ... 547
Maltby anticlinal, description of, ... 406
" colliery, buried valley at, ... 642
" " elevations at, ... 390
" " operator and beds worked, ... 370
Mallory, Judge Garrick, limestone quarried on farm of, ... 486
Mammoth coal-bed, analysis of specimens from, ... 321
" " " (E. M. C. F.,) 313

Page.
McKinney, R. M., property surveys, ... 159
McKnight mine. 213
McMurray's Mill well, no market for gas from, ... 35
McNair, T. S., assistance afforded Survey by, ... 352
McQuiston pit, ... 196
Meeting House hill, triangulation station, ... 698
Mehoopany coal field, location and extent of, ... 460,486
" " named the Western Northern, ... 284
" " structure of, ... 284
Meigs, General M. C., researches in value of coals, ... 308
Melanchyme, ... 654
Mercer twp., Butler co., gas wells, ... 35
Meridian line, location at Wilkes Barre, ... 361
" used on Coast and Geodetic Survey, ... 682
Merriam colliery, analysis of coal and ash, ... 323
Merriman, Prof. Mansfield, appointment on triangulation survey, ... 694
" " report on triangulation of Penna., ... 681
Mesozoic formation at Cornwall, ... 525
" s'rata, Cornwall, obscure exposures of, ... 495
Me'ers into feet, constant used on C. and G. survey, ... 696
" " miles, " " " " " 696
Meunier, C., tests of coals, ... 308
Meylert opening on coal-bed A, ... 466
" " re-opened 1886, ... 466
" " composition of specimens from, ... 318
" coal, a semi-anthracite, ... 470
Midvale colliery, operator and beds worked at, ... 370
" " elevations, ... 397
Middle and Western Penna.. erosion in, ... 575
Middle Hill, Cornwall, elevation of, ... 491
Mifflin twp., Allegheny co., elevations, ... 145
Milesville, ... 168
" mines. 220
Mill Creek colliery, elevations at, ... 396
" limestone bed, fossils found in, ... 438
" slope anticlinal, ... 409
" " basin, ... 409
" Slackwater Navigation Co., ... 443
Mill Hollow colliery, ... 389
" shaft, Ross and Red Ash coal-beds, ... 386
Miller's coal, ... 161
" creek, relation to pot-hole, ... 623
" pit, not examined, ... 183
Mills coal-bed, Mine Sheet, No. III, position relative to Pottsville conglomerate, ... 372
Mine Hill Gap colliery, analysis coal and ash from, ... 323
Mine map Bernice mines, brought up to February, 1884, ... 473
Mineral charcoal, figure showing structure of, ... 122
Minerals found at Cornwall mines, ... 546
Mine sheets, description of area embraced by, ... 292
Miner, Charles, assisted on survey of Northern Coal-field, ... 354

Miller's Mill borough to Solomon's gap, outcrop of Baltimore traced from, 392
Mineral Spring colliery, elevations at, ... 396
" " operator and beds worked at, ... 370
Mining of coal, chapter on, ... 296
" of Cornwall ore, ... 549
Mocanaqua, inclination of anticlinals in vicinity of, ... 400
" -Warrior Run anticlinal, ... 417
Monongahela division Penna. R. R., elevations, ... 185
" river slackwater, elevation of pools on, ... 196
" twp., Greene county, elevations, ... 153
Monopteria (Pterinea) gibbosa, ... 444,455
Montana, (Mine Sheet No. IV,) areas near, ... 348
" triangulation s ation, ... 699
Moore pit, coal opened at, ... 214
Moosic triangulation station, geographical position of, ... 697,705
Morgantown sandstone, ... 179
Morrell, Mr., analysis of dry gas by, ... 677
Morris cross-roads, ... 166
" G., aided in preparation Mahanoy and Shenandoah map, ... 333
" " map L. & W. C. Co.'s workings, ... 358
" Israel W., map furnished Survey, ... 345
Montour, gas furnished Pittsburgh from, ... 38
Morton pit, Pittsburgh coal opened, ... 192
Mount Pleasant twp., Washington county, nothing but gas obtained in wells, ... 26
Mt. Carmel shaft colliery, analysis of coal and ash, ... 323
" Hope, ... 494
" Jefferson, triangulation station, geographical position, ... 705
" Nebo well, Ohio twp., Beaver county, Thorn creek sand in, ... 25
" Pleasant Branch, P. & C. R. R. elevations, ... 183
Moyer, H. I., assistant in Northern Coal-field, ... 354
Munroe, Professor Charles E., valuation of coal, ... 307
Murraysville anticlinal, formation of, ... 47
" axis, ... 49
" " full of water going north-east, ... 49
" " same as Peter's creek axis, ... 161
" anticlinal, ... 165
" district contributing gas to Pittsburgh, ... 38
" " wells drilled in, ... 10
" gas belt, area of, ... 662
" " field, description of, ... 38
" " from Venango-Butler group, ... 38
" " horizons furnishing gas, ... 10
" " wells, depth of the first, ... 662
" " " great force of gas at, ... 669
" pool, present draft on, ... 52
" " pressure of gas in, ... 39,666
Myalina subquadrata, ... 446,454,456

N.

Page.

Nanticoke dam, elevation, ... 630
" gap, thickness of drift at, ... 631
" mine disaster, reference to, ... 615
" Mine Sheet, No. III, ... 372
" Station, L. & S. R. R., line of outcrops from, ... 632
" Susquehanna river at, ... 637
" triangulation station, geographical position of, ... 705
Natural-gas of Pennsylvania, paper on, ... 657
" current price of, ... 678
" Pittsburgh areas, ... 1
" displacement of coal by, ... 673
" Youngstown, Ohio, ... 35
" popular fallacies concerning, ... 51
" variation in chemical composition, ... 674
" " fuel value of, ... 675
" S. A. Ford, analysis of, ... 675
National kaolin works, analysis of kaolin, ... 589
" " limestone outcrop at, ... 581
" " shaft at, ... 599
" " situation of, ... 598
" " plan of, ... 610
" " pit, no rock found *in situ*, ... 601
Neal & Oliver works, coke produced at, ... 176
Nescopec twp., glacial moraine running through, ... 616
New Brighton gas supply, ... 41
Newcastle pipe-line. 35
New coal-bed, Hillman colliery, ... 391
" " where mined in Northern Coal-field, ... 369
" fields, in areas below Venango oil group, ... 79
" Garden twp., Chester county, kaolin exposures near a limestone belt in, 577
New Hampshire, thickness of ice in Ice Age, ... 615
New Jersey, tree trunks beneath peat in, ... 109
" primary triangulation. Penna. triangulation commenced on, 693
New Orleans, beds of peat in borings near, ... 109
" Red measures against trap at Cornwall, ... 527
Newport Centre anticlinals, ... 418
" Creek " 419
" " valley, bore-holes to test drift in, ... 629
Newton well, Oil Creek twp., Crawford county, ... 34
Newtown basin, ... 414
" triangulation station, geographical position of, ... 704
" Mt. Rose primary triangulation line, ... 694
New York oil fields, ... 49
" State Geological Survey, geological nomenclature proposed by, 287
" and Cleveland Gas Coal Co., ... 177
" State line, triangulation in Penna. extended across, ... 697
" " survey, triangulation of, ... 698
Nesquehoning tunnel, section of, ... 290
" mountain, Pocono coal, ... 254
Nettleton, Mr., production Phillips well, ... 25

Niagara shaft, quicksand in, ... 640
Nicholson twp., Fayette county, elevations in, ... 157
Niles, Allegany district, New York, ... 13
Nine Mile run, ... 165
Nineveh synclinal, ... 167
Nineveh-Allegheny synclinal, ... 167
Noel, James, supt. Savage Fire Brick Company, ... 245
North Ashland colliery, analysis of coal and ash from, ... 328
" Huntingdon township, Westmoreland county, elevations in, . . . 155
" Mahanoy colliery, analysis of coal and ash from, ... 321
" Mountain, Sullivan county, ... 459
" " Pocono coal on, ... 254
" " Virginia, ... 284
North Savage Fire Brick Company's mine, ... 239
North Savage Fire Brick Company's mine, section, ... 243
" Sea, formation of bog near, ... 115
" Versailles township, Allegheny county, elevations, ... 143
" Versailles township, Allegheny county, position of Pin Hook axis in, 161
Northern coal-field, additional parts to atlas, ... 365
" " anticlinals and basins, ... 396
" " estimates of coal, ... 367
" " extent of, ... 276
" " field work necessary in, ... 360
" " location of sections, ... 291
" " percentage coal mined, ... 296
" " plan of work, ... 363
" " published sheets, ... 364
" " progress of work, ... 272
" " scale of maps, ... 360
" " structure of, ... 284
" " survey of, ... 353
Nottingham colliery, elevations at, ... 379
" " cars hoisted, ... 378
" " operator and bed worked, ... 370
" " red ash bed worked at, ... 377
" township, Washington county, ... 151

O.

Oakwood colliery, elevations at, ... 396
" " haulage way in Four Foot bed, ... 392
" " operator and beds worked at, ... 370
" " maximum thickness of Four Foot bed, ... 393
Obburg, Switzerland, peat bog at, ... 653
Ocean mines, Nos. 1, 2, 3, and 4, location of, ... 200
" " No. 2, description of, ... 201
" " Nos. 3 and 4, description of, ... 201
Ohio, prospecting for oil and gas in, ... 2
Ohlen, H. C., record of wells received from, ... 83
" well, No. 1, record of, ... 85
" " No. 2, record of, ... 86
" " No. 3, record of, ... 88

Page.
Ohlen well No. 4, record of, ... 91
Oil, First, Second, and Third sands, character of, ... 63
Oil borings, Jackson and Abbott townships, Potter county, ... 82
Oil City *Derrick*, letter published in, by request of State Geologist, . . . 58
Oil Creek Third sand, names applied to different parts of, ... 65
" " no evidence of oil-sand below, ... 62
Oil Creek Valley, sand-rock in, ... 66
Oil and gas horizons, sections, ... 5
" " " Westmoreland, Allegheny, Beaver, and Washington counties, ... 9
Oil and gas, preliminary report on, J. F. Carll, ... 1
" " uncertainties in operating, ... 37
Oil-sands, age of deposit, ... 71
" " comparison of. 79
" " composition of, ... 61
Oil-sands, nomenlcature of, ... 64
Oil-sand belt, ... 67
Oil-sands group, ... 64
" " between Tidioute in Warren county, to St. Joe in Butler county, ... 61
Oil-region map, construction of, ... 12
Old Bennett coal-bed, in Northern Coal Field where mined, ... 368, 372
Old Eagle mine, ... 214
Olean, gas from Allegany oil-district piped to, ... 31
Olean conglomerate in Boyd's Hill well, Pittsburgh, ... 5
" " key to structure of oil regions, ... 4
" " outcrop at Olean Rock City, ... 5
" N. Y. line of glacial epoch at, ... 615
" Rock City, outcrop of Olean conglomerate at, ... 5
Oligoclase in feldspar rocks, ... 585
Olyphant triangulation station, ... 705
O'Neil's, H. D., coal not classed as Pool, No. 3, ... 205
O'Neill mine, ... 190
" " section of Pittsburgh bed at, ... 191
Opal, the common, found at Cornwall, ... 547
Orchard coal-bed, analysis of specimen from, ... 321
" " Northern Coal-Field, where mined, ... 368, 372
Order No. 3 to Survey assistants relative to information obtained, ... 356
" to Survey corps relative to unpublished information, ... 359
Ore, internal constitution of the Cornwall, ... 530
" mass in Big hill, ... 508
" " Middle hill, ... 509
" run, Sullivan co., bed of ore exposed on, ... 489
Origin of coal, notes by J. P. Lesley on the, ... 121
Orthoclase in feldspar rocks, ... 585
Orthonota, ... 446
Orton, Dr. Edward, doubt as to reported gas pressures, ... 663
Overturned anticlinal near Lebanon, ... 545

Pacific mine, ... 204
Page plate, Archbald pot-hole, ... 618
" " " sections of, ... 620
" Anticlinals and synclinals, Pittsburgh-Monongahela district, . 126
" Brandywine Summit kaolin pits, ... 592
" " " " works, ... 596,612
" Bell magnetic ore mines, Dillsburg, ... 566
" Bernice coal basin, ... 460
" Cornwall, Big hill, section across, ... 498
" " " trap at, ... 501
" " " and Middle hills, sections through, ... 510
" " Middle hill, little railroad cut and sections, ... 516
" " " magnetic iron ore workings, ... 510
" " " ore stopes in, ... 508
" " " stratification of ore mass, ... 512
" " " prongs of trap, ... 504
" " crush fault, ... 542
" " iron ore mine, ... 492,494
" " " " cross sections of, ... 506
" " limestone ridge, section at west end of, ... 520
" " section along R. R., ... 526
" " stopes and prongs of trap, ... 502
" " internal constitution of a block of Cornwall ore, . . 530
" Germania Oil Co.'s test wells, ... 84
" " " " sections of, ... 92
" horse-shoe triangulation in Penna., ... 696
" internal vegetable structure of coal, ... 122
" Loop run and Tunnel openings, Tipton, ... 260
" McCormick magnetic ore mines, Dillsburg, ... 568
" National kaolin works, ... 610
" Old Buried Valley, Kingston and W. Pittston, ... 638
" Savage Fire Brick Co.'s mines, ... 240
" " " " " sections at, ... 242
" Wilkes Barre fossils, ... 440,442,444,446
Palissy, Bernard, opinion on origin of plants found at Gies, ... 96
Panther Creek Basin at Tamaqua, section of, ... 327
" " cross section of, ... 283
" " extent of, ... 275
" " depths of points in, ... 286
" " high-dipping beds of, percentage coal taken from, . . 297
" " measurements for sections of, ... 328
" " results of analyses of coals from, ... 310
" " survey completed between Mauch Chunk and Tamaqua, ... 325
Panther Creek region, statement of waste of coals in, ... 298
" triangulation station, geographical position of, ... 697,705
Pardee, Ario & Sons, assistance offered Survey by, ... 352
Parrish colliery, operator and beds worked, ... 370
" H. E., assistant in Northern Coal Field, ... 354
Peat, growth of, hastened by a humid atmosphere, ... 112

Peat bogs in low countries more extensively formed along sea shore, . . . 115
" " definition of, ... 106
" " implements found in, ... 117
" " in valley of the Brèvine, ... 107
" " of Denmark, animal remains in, ... 111
" " of Les Ponts, Jura, ... 112
" " on steep slopes, ... 112
" " forest in Switzerland, ... 107
" " Scranton, "Dopplerite" from Post Glacial, ... 615
Peat bog theory of formation of coal, ... 105
Peat deposits, ... 118
" " of Denmark, ... 107
" " " Sweden and Denmark, ... 109
" " " Virginia, ... 106
Peat formation, thickest lacustrine, ... 114
Peckitt, Leonard, analysis of ore by, ... 537
Pennsylvania anthracite fields, ... 319
" Coal Co's. property, bore-holes on, ... 641
" furnace, Centre co., ... 515
" Gas Coal Co., coal shipped by, ... 176
" mine, ... 176
" no system of description of boundary lines in, ... 685
" Railroad Co., coal lands, ... 351
" " elevations along, ... 128
" " formations passed through, ... 256
" " tunnel, Upper Freeport coal-bed cut in, ... 256
" Salt Manufacturing Co., Natrona, gas supply, ... 38
" south-west corner of, geographical position of, ... 706
Penn twp , elevation in, ... 142
Penny mines, ... 153
Penobscot triangulation station, geographical position of, ... 689,693,705
People's Heat and Light Co., ... 26
" Natural Gas Co., ... 39
Permian formation, Wilkes Barre fossils reported to be, ... 439,441
" fossils, Wilkes Barre collection contain no, ... 450
Perry, John & Co., ... 219
Petersburg triangulation station, geographical position of, ... 705
Peter's creek, ... 160
" " anticlinal, ... 165
" " axis, ... 160
" " " extension of, ... 159
" " " occurrence of, ... 159
" twp., elevations in, ... 151
Petrolia, first oil-sand, ... 8
Petroleum, outflows of, accounting for the occurrence of bitumen, ... 108
Petroleum Age, oil statistics from, ... 18
" " " " Allegheny district, ... 12
" " " " Bradford " 15
Petty's Pond basin, ... 415
Philadelphia, old High School observatory, geographical position of, . . . 706
" State House, geographical position of, ... 705

Page.
Philadelphia, St. Peter's Church, geographical position of, ... 705
" Water Dept., determinations by, ... 706
" Co., in Murraysville field, ... 89
" " manufactories supplied with gas by, ... 679
" " piping gas to Pittsburgh, ... 38
" feldspar rocks, ... 584
" and Reading Coal & Iron Co. collieries analysis of coals from, 321
" " " authority for section in Pottsville basin, . . . 329
" " " completeness of maps of, ... 333
" " " mining engineers of, ... 333
Phillip's well No. 1, ... 24
" " on Oil creek, ... 25
" " Thorn creek, ... 21
Phillipsburg, gas supply of, ... 41
Phillipsia sangamonensis, ... 446,458
Phœnix Park colliery, ... 823
" pit, ... 164
Pholas candida, ... 117
Phytocollite. 656
Pierce family, farms of, ... 194
Pigeon run, drift in coal on, ... 475
" " Sullivan co. ore exposed on, ... 489
Pimple Hill triangulation station, geographical position, ... 691,705
Pin Hook anticlinal, ... 160,162,164,167
" " village, ... 165
Pine Creek village, ... 36
" Forest colliery, analysis of coal from, ... 323
" Grove, analysis of coal specimen from near, ... 309
" Ridge colliery, elevations at, ... 396
" " " operator and beds worked at, ... 370
" " " small coal-bed at, ... 392
Pinna peracuta, ... 444,454,455
Pioneer furnace, ... 278
Pithole, character of oil at. 63
Pittsburgh, development of gas area, surrounding, ... 1
" elevations in, ... 139,140,142
" coal-bed, cleavage of, ... 177
" " commercial importance of, ... 171
" " current deposition of, ... 103
" " description of, ... 173
" " in Forward twp., ... 206
" " key to structure in oil-regions, ... 4
" " measurements above and below, ... 171
" " outcrop line of, ... 127
" " outcrop near Reynolds, ... 161
" " sections, at Atlantic mines, ... 204
" " " Bellevue mine, ... 185
" " " Corneil & Werling mine, ... 188
" " " Henderson's lower pit, ... 199
" " " " upper pit, ... 199
" " " Horner & Roberts mine, ... 209

Page.
Pittsburgh coal-bed sections, Lovedale mine, ... 193
" " " Ocean mine, No. 2, ... 203
" " " Old Eagle mine, ... 215,217
" " " O'Neill mine, ... 191
" " " Rankin mine, ... 219
" " " Walker mine, ... 212
" " " Winona mine, ... 218
" " structural features of represented, ... 162
" " successful wells in Washington county below, ... 26
" " top of Barren Measures, ... 178
" " wells in Dunkard creek district 600 feet below, ... 28
" gas fields, ... 49
" Cincinnati & St. Louis R. R., elevations along, ... 138
" gas areas at, ... 670
" McKeesport & Youghiogheny R. R., elevations along, ... 134
" -Monongahela district, map of, ... 126
" region, geographical limits of, ... 125
" " map of, ... 159
" gas wells, source of supply, ... 4
" region, structure of, ... 159
Pittston, Luzerne county, Susquehanna river at, ... 637
Plains-Yatesville anticlinal, ... 406
Plank Ridge colliery, analyses of coal and ash from, ... 322
Platt, Franklin, Kramer & Hart drift examined by, ... 263
" reference to bore-hole record of Bernice coal property, 468,469
" report on waste of anthracite, ... 333
" reported on Loyalsock and Mehoopany fields in 1878, . . 462
Pleasantville, character of oil at, ... 63
Plymouth collieries, identity of coal-beds at, ... 378
" No. 2 colliery, operators and beds worked, ... 370
" " " shaft and rope drill bore-hole section, ... 427
" No. 3 " operator and beds worked, ... 371
" No. 4 " " " " 371
" No. 5 " analysis of Bennett bed, ... 314
" " " " Cooper bed, ... 314
" " " operator and beds worked, ... 371
" Mine Sheet, No. V, ... 376
Policy governing field corps, ... 358
Pollock's run, ... 165
Polly Elliott and Wm. Hall tracts, coal smut reported on, ... 488
Pontypridd, South Wales, section near, ... 99
Pool No. 3, unjust discrimination against, ... 205
Pool Theory, remarks on the, ... 45
Popular fallacies regarding precious metal deposits, ... 42
Port Blanchard, buried valley at, ... 639
" Clinton triangulation station, ... 690
" " " " geographical position of, ... 702
" Royal, ... 168
Pot-hole at Archbald, ... 615
" location of, of importance to coal operator, ... 616
Potter county, one spot colored on map for gas, ... 31

Potter county, possibility of productive oil-fields in, ... 52
Pottsville, analysis of coal from, ... 309
" basin, section in, ... 329
" " measurements of section in, ... 330
" coal-field, extent of, ... 275
" colliery, analysis of coal and ash from, ... 323
" conglomerate, thickness in Wilkes Barre mountains, ... 393
" " crests of Savage mountain made by, ... 228
" " cross sections in Northern Coal-field, ... 363
" " explorations for coal in. 393
" " Hanover colliery bore-hole sunk to, ... 375
urt-house, geographical position of, ... 706
on and Steel Co., ore used in furnace of, ... 585
luctions from notes in Chapter V, ... 76
gas-wells, greatest known, ... 663
1, colliery, analysis of coal and ash from, ... 325
. 3 and 4 collieries analysis of coal and ash from, ... 322
l-bed, analysis of specimen from, ... 321
" Western Middle Coal-field, analysis of, ... 313
" Southern Coal-field, analysis of, ... 313
imuth observed at. 688
leetinghouse, primary triangulation line, ... 694
of ore at Cornwall for the year 1885, ... 561
oil and gas horizons discovered since 1882, ... 3
neasures, Lincoln twp., Allegheny county, exposures of, . . 184
ora, ... 440,452
ebrascensis, ... 453
liery, elevations. 388,396
" depth of workings in, ... 285
" operator and beds worked at, ... 371
ft anticlinal, ... 410
basin, ... 409
triangulation station, geographical position of, ... 705
vernmental surveys, angle measurements on, ... 692
ast Survey, angle measurements on, ... 692
triangulation station, geographical position, ... 705
y, analysis of coal and ash from, ... 323
. . . . 654
ound at Cornwall, ... 548

Q.

geology of Wyoming-Lackawanna Valley, ... 615

R.

els, ... 123
rth Carolina, once covered by tertiary strata, ... 576
coming county, Rankin mine, ... 218
triangulation station, ... 694, 701
liery, No. 1, elevations, ... 395
" No. 1, operators and beds worked, ... 371

Red Ash colliery, No. 2, elevations, ... [illegible]
" " thickness of No. XII, at, ... 289
" coal-bed, average thickness Mine Sheet, No. VIII, ... 393
" " relation to Baltimore bed, ... 378
" " consisting of one bench, ... 361
" " immediately over Pottsville conglomerate, ... 372
" " Kingston and Mill Hollow collieries, ... 396
" " maximum thickness of, ... 377
" " Mine Sheet, No. V, ... 377
" " mining value of, ... 396
" " no commercial coal below, ... 393
" " where mined, ... 368
Red Hematite, Grassy Hill, Cornwall, ... 518
Redstone coal-bed, ... 173
" " character of, ... 206
" " opened near Morton pit, ... 198
" " outcrop of, ... 184, 198
" " on Pierce's fork, Howell's creek, ... 194
Red Valley pool, Venango county, ... 1
" " " oil-sand of, ... 22
" well, ... 25
Relief bore-hole, Nanticoke, record of, ... 638
Regnault, researches on the origin of coal, ... 99
Report I4, ... 33
" GG, ... 317
" " analyses, ... 477
" " Geology, Lycoming and Sullivan county, ... 462
" K, location of Peter's creek axis, ... 159
" KK, location of Peter's creek axis, ... 159
" MM, analysis, ... 477
" Bernice coal basin, ... 460
Reynolds', (McKeesport,) outcrop Pittsburgh coal, ... 161
" colliery, elevations at, ... 379
" " operator and beds worked at, ... 371
" Fault anticlinal, ... 420
Rhodochrosite, at Cornwall, ... 548
Rhume Run tunnel, names of, ... 288
" " section of, ... 289
Richards & Hartley bottling works, supplied with gas from Bull creek field, 38
Richardson colliery, analysis of coal and ash from, ... 322
Richburg well, date of development, ... 13
Richmond, Virginia, coal first mined in the United States at, ... 277
Ricketts, Col., section by, ... 459
" triangulation station, ... 705
Ridge mine, Eaton colliery, pot-hole at, ... 617
" theory in locating oil-wells, ... 43
Riley, L. A. & S. M., Locust Mtn. Coal and Iron Co., map made by, . . . 345
Rixford gas pool, Bradford gas supply from, ... 31
Roaring Run anticlinal, ... 165
" " " same as Peter's creek axis, ... 161
Robesonia Iron Co., ... 517

Page.
Robesonia Iron Co., method of mining, ... 509
" " mining at Cornwall, ... 557
Robins & Jenkins mine, ... 182
Rochester, Bridgewater field supplying gas to, ... 40
" on Ohio river, wells drilled for gas, ... 26
" Tumbler Co., ... 26
Rock-gas, composition, ... 671
" current prices, ... 678
" fuel-value, ... 672
" pressure, ... 657
" quantity, ... 666
Rogers, Prof. H. D., analysis of Pennsylvania anthracites, ... 309
" " identification of Cornwall slates, ... 540
" " naming of formations by, ... 288
Rock coal-bed, where mined, ... 368
Ross " average thickness on Mine Sheet, No. VIII, ... 393
" " extensively worked on Mine Sheet, No. VI, ... 382
Rostraver twp., Westmoreland co., elevations, ... 154
Rothrock, Prof. J. T., sections of seeds by, ... 649
Rothwell, R. P., topographical map Panther Creek basin, ... 326
" " Wyoming map by, ... 360
Round Hill church, great limestone and Uniontown coal-bed, ... 194
" Top triangulation station, ... 695,705
Roy well, Elk co., ... 3
Roy & Archer gas-pool, horizon of gas and oil in, ... 32
" " three wells composing, ... 32
Rupert pit, ... 197

S.

Sadtler, S. P., analysis of rock-gas, ... 675
" " gas analysis, Report B, ... 668,672
Salem colliery, operator and beds worked at, ... 371
" triangulation station, ... 697,705
Salom & Westesson, analysis by, ... 467
Salt water rock at Pittsburgh, ... 9
Saltsburg anticlinal, ... 166
Sandy creek, ... 165
" epoch, ... 69
Sargassum, floating fields on Atlantic, ... 104
Sargeant pool, geyser well in, ... 31
Sartwell, deeper sands not found near, ... 15
Sartwell-Smethport, Roy & Archer well in, ... 3
Savage Fire-Brick Co., driving machinery of, ... 245
" " " map of mines, ... 240
" " " second opening, ... 244
" valley, drainage of, ... 228
Saw Mill dam, Loop run, coal opened near, ... 259
Saxon station, gas deposits near, ... 36
" well, lamp-black made at, ... 36
Scharar, Chris. H., collection of fossils by, ... 439

Page.
Scharar, Chris. H., Mill Creek limestone found by, ... 447
" " " " identified, ... 445
" " Wilkes Barre fossils belong to, ... 451
Scheurer-Kestner, coal test by, ... 308
Schizodus cuneatus, ... 442,456
" " *wheleeri*, ... 442,456
Schlotheim, researches on origin of coal, ... 96
Schooley air shaft, strata cut in, ... 640
" main " quicksand at, ... 640
Schott, C. A., longitude determinations by, ... 707
Schuylkill colliery, analysis of coal and ash from, ... 322
" red ash coal defined, ... 305
" region, production previous to 1858, ... 330
Scott, Chas. B., work in Northern Coal-Field, ... 354
" W. L., large area Pittsburgh coal-bed owned by, ... 200
" Ocean mine, No. 2, ... 169
" twp., Allegheny co., elevations in, ... 144
Scranton court house, ... 705
Scranton, "dopplerite" from, ... 615, 647
" in glaciated portion of slate, ... 648
" mineral, low percentage of carbon in, ... 654
Scrub Grass and Emlenton, apparent break in oil belt between, ... 70
Second oil-sand, character of oil from, ... 63
" and First oil-sand, confusion in naming, ... 66
Section A, Northern Coal-Field, ... 363
" A bed, Meylert drift, ... 467
" A and B beds, Bernice basin, ... 468
" anthracite coal measures, Atlas Sheet, ... 292
" Archbald pot-hole, ... 620
" Barren series, ... 178
" B, Northern Coal-Field, ... 363
" B bed, Bernice basin, ... 473
" " Old Jackson mine, ... 472
" bore-hole, S. E. Bernice opening, No. 1, ... 474
" " Bernice coal opening, ... 468
" C, Northern Coal-Field, ... 364
" Chrisman coal-bed, ... 487
" coal measures, Bell's tunnel and Pott's collieries, ... 343
" " Drifton and Lattimer collieries, ... 349
" " Ellangowan and Indian Ridge collieries, ... 341
" " Preston and Girard Mammoth collieries, ... 342
" " Mine Sheet, No. III, ... 423
" " " No. IV, ... 376
" " " No. V, ... 427
" " " No. VI, ... 429
" " " No. VII, ... 432
" " " No. VIII, ... 433
" " Northern Coal-Field, unfinished, ... 363
" " Primrose colliery and East Mahanoy tunnel, ... 339
" " Wyoming Valley, showing limestones, ... 449
" Cornwall, along railroad, ... 526

Page.
Section, Cornwall, Big Hill and Furnace creek, ... 498
" " Big and Middle Hills, ... 510
" " crush fault, ... 542
" " limestone ridge, west end, ... 520
" " Middle hill, ... 502
" " mine, ... 506
" Duncan station, P. McK & Y. R. R., ... 197
" fire-clay bed near Ellerslie, ... 248
" Germania Oil Company's well, ... 92
" John's farm, ... 600
" Kaolin bed. Griffin farm, ... 594
" Nesquehoning tunnel, ... 290
" North Savage mine, ... 243
" Ore run, Sullivan county, ... 489
" Vertical cross section of Palæzoic strata, Carbon county, ... 281
" Panther creek basin, Tamaqua, ... 327
" " coal-basin, ... 283
" peat, M. H. Debray, ... 116
" peat bog, Valley of the Somme, France, ... 118
" Pontypridd colliery, South Wales, ... 99
" Pottsville basin, ... 329
" Ross coal-bed, "Harry E." tunnel, ... 366
" system of shading by survey, ... 296
" Towanda mountain, Prof. Lesley, ... 490
" Upper Productive coal measures, ... 172
" Wellersburg bore-hole, ... 231
" No. 1, showing oil and gas horizons, ... 5
" No. 2, based on ferriferous limestone, ... 6
" No. 3, based on Pittsburgh coal-bed, ... 6
Semple, Boyd & Arstrong, No. 2 well, torpedoing of, ... 22
Serpentine found at Cornwall, ... 547
" exposure along Chester and Darby creeks, strike of, ... 572
Sewickley coal-bed, ... 173
" " Forward township not noticed in, ... 206
" " on Pierce's fork, Howell's creek, ... 194
" creek, ... 165
" township, Westmoreland county, elevations in, ... 155
Seven Foot coal-bed, analyses, ... 313
Shaft coal-bed, where mined, ... 371
Shamokin, difficulty in systemating maps near, ... 346
" coal, definition by J. S. Harris of, ... 305
Sharp Mountain Gap, coal-bed T most southern bed in, ... 328
Sharples & Shoemaker's quarry, orthoclase found in, ... 589
Sheafer, A. W., aided on Mahanoy and Shenandoah Sheets, ... 333
" " charge of Western Middle Coal-Field party, ... 334
" " Northern Coal-Field work commenced under direction of, 358
Sheafer, P. W., diagram and tables (report AA.) by, ... 326
" " "dopplerite" described in letter to, ... 648
Sheep Hill, Cornwall, ... 495
Sheerer, analysis of orthoclase by, ... 586
Sheffield gas pool, discovered by Hague or Sheffield well, ... 32

Page.
Sheffield gas pool, most prolific in country, ... 32
" " " product piped to Warren junction, N. Y., ... 33
Shenandoah City colliery, analysis of coal and ash from, ... 322
" district, waste in preparing Mammoth bed coal, ... 299
" Mine Sheet, No. II, ... 339
" " " " II, beds worked on, ... 340
Sheridan station, Pan Handle railroad, ... 164
Shickshinny, suggested outlet for buried valley at, ... 631
" triangulation station, ... 697,705
Shingle House, Potter co., gas piped to consumers at, ... 31
Shinn, W. P., on consumption of gas, ... 673
Shoemaker, W. S., bore holes on property of, ... 641
Sideling Hill, No. X coal-beds in, ... 251
" " tunnel East Broad Top R. R., section, ... 252
" " " South Penn R. R. coal-beds in, ... 254
Sidney station, P. McK. & Y. R. R., ... 184
Sierra Madre, Permian deposits of the, ... 451
Sigillaria, figures showing structure of, ... 123
Siliceous limestone Boyd's Hill well, ... 6
" " Pittsburgh and Little Washington wells, ... 6
Sink holes, Chester co., ... 581
" " none in Delaware co., ... 582
Six-Foot coal-bed, where mined, ... 369
Skidmore coal-bed, analysis of, ... 321
Sims, H. N., assistant, Western Middle Coal-field, ... 334
Slippery Rock twp., Butler co, gas-wells in, ... 35
Slickensides, production of, ... 660
Smethport, deeper sands not found in wells near, ... 15
" sand, geological horizon of, ... 16
Smith, A. D. W., assistant, Northern Coal-Field, ... 354
Smith's Bridge station, W. & R. R. R., elevation, ... 583
Smith's Ferry, change in rocks developed at, ... 11
Smithfield, ... 166
Smith's gap triangulation station, ... 689,691,699,704
Snake Island coal bed, Hillman colliery, ... 391
" " " " where mined, ... 369
Snowden twp., Allegheny co., elevations, ... 148
Snyder well, gas struck in, ... 35
Solomon's gap, outcrop Baltimore bed traced to, ... 392
Somerset county, south-eastern corner, ... 227
Somme, France, formation of bogs near mouth of, ... 118
" " section of peat bog in valley of, ... 118
South mountains, limestone strata of Lehigh Valley once covering the, . 575
" Versailles twp., Allegheny co., elevations, ... 144
" Wilkes Barre colliery, elevations, ... 383
" " " operator and beds worked at, ... 371
South-West Penna. R. R., elevations, ... 129
" " " extension, elevations, ... 130
" Gas Coal Co. mine, ... 198
Southern coal-field, extent of, ... 275
" " published sheets relating to, ... 325

Page.
Southern coal-field, survey of, ... 325
" " topographical map of, ... 332
" " table showing location of sections, ... 291
Speechley farm, Cranberry twp., well on, ... 34
Spencer, Mr., kaolin mined by, ... 573
Sphagna, growth of, ... 107,111,120
Spirifer lineatus, ... 453
Spring Brook, No. 5, colliery, analysis of Mammoth and Wharton beds, . 314
" Hill twp., Fayette co., elevations in, ... 157
" Mountain, No. 4, colliery, analysis of Mammoth and Wharton bed, 314
St. Joe, Butler co., to Allegany co., N. Y., drillings between, ... 3
St. Nicholas colliery, analyses of Mammoth and Buck Mountain beds at, . 315
Stanton anticlinal, ... 413
" basin, ... 414
" bore-hole anticlinal, ... 415
" (No. 7) colliery, elevations, ... 383
" " " representing section, Mine Sheet, No. VI, ... 429
" " " operator and beds worked at, ... 371
" overturn, ... 400
State Line & Sullivan R. R. Co., coal areas owned by, ... 461
" " " estimates of coal on property of, ... 476
" " " offer to Survey by, ... 462
Stearns, I. A., assistance rendered Survey by, ... 352
" bore-hole records received from, ... 646
" general superintendent Susquehanna Coal Co., ... 628
Steadman, A. W., L. V. R. R. surveys directed by, ... 462
Sternberg, researches on origin of coal, ... 96
Sterrett pit, ... 164
Stevenson, Prof. J. J., ... 177
" " Peters Creek axis located by. 159
Stigmaria lepidodendron in Breckenridge coal of Kentucky, ... 98
Stine Bro.'s mine, coke produced at, ... 176
Stinson, J. M., analysis of "dopplerite" by, ... 651,655
Stopes in Middle hill, sketch of, ... 502
Stratification of ore mass, Cornwall, ... 513
Strattonville, Clarion co., gas spot at, ... 85
Street's Run synclinal, ... 167
Stringtown mine, ... 198
Strong, Henry K., section near Wellersburg, ... 229
Stroud & Ackley's saw mill, shaft sunk near, ... 475
Stowell's Petroleum Reporter, production of Warren district from, . . . 19
Stultz, Mr., information received from, ... 248
Sturdevant, Wm. H., assistance relative to property lines rendered by, . . 362
Sub-olean conglomerate, key to structure of oil regions, ... 4
Sucker rod system of well drilling, ... 19
Sugar Notch (No. 10) breaker anticlinal, ... 417
" collieries, Red Ash bed, one bench worked at, ... 381
" " tendency of coal-beds to thin and thicken at, . . 376
" No. 9 colliery, elevations, ... 383
" " operator and beds worked at, ... 371
" " thickness of beds worked at, ... 382

Page.
Sugar Notch, No. 10 colliery elevations, ... 384
" " operator and beds worked at, ... 371
" tunnel anticlinal, ... 417
Sullivan co. coals, peculiarity of, ... 484
" location of North mountain, ... 459
Summit Coal Co., predecessor of Tipton Run Coal Co., ... 250
" Hill, Carbon co., triangulation station, ... 705
" " mines, early shipments from, ... 278
" " " system of mining at, ... 297
" " village, coal first quarried in 1792 near, ... 290
Surveys between Bernice and the Susquehanna river, ... 462
Survey, method of representing strata, ... 282
" of the Southern Coal Field 325
Susquehanna Coal Co.'s collieries, elevations, ... 374
" " " operators and beds worked at, ... 371
" " " No. 1 shaft, section of, ... 423
" " " No. 2 shaft, section of, ... 425
" " " Nos. 1 and 2 shafts, section of, ... 373
" " " Slope No. 1, disaster at, ... 617,627
" " Co. topographical map of vicinity of Nanticoke, . . 632
" river, mean low water of, ... 630
Swatara Gap, triangulation station, ... 695
" " " " geographical position of, ... 705
Szabo's test of feldspars. 587

T.

Table, analysis average composition Penna. anthracites, ... 318
" " coals and ash from anthracite collieries, ... 322
" " coals, collieries of P. & R. C. & I. Co., ... 321
" " coals, Panther Creek and Lehigh basins, ... 310
" character of coal, number producing collieries, etc., ... 304
" coal-beds, thickness, etc., mined on Nanticoke Mine Sheet, No. III, . 372
" " " " " " Plymouth Mine Sheet, No. V, . 377
" " " " " " Ashley Mine Sheet, No. VI, . . 381
" " " " " " Kingston Mine Sheet, No. VII, . 384
" " " " " " Wilkes Barre M. S., No. VIII, . 391
" collieries, operators and coal-beds on N. Coal Field Sheets, . . . 368,372
Table, depths of some of the anthracite basins, ... 285
" different kinds of coal in different fields, ... 304
" example triangulation observations, ... 689
" amount and price, copper ore, Cornwall, ... 548
" cost of ore and iron at Cornwall from 1848-1858, ... 554
" " at Cornwall from 1864-1876, ... 560
" " mining at Cornwall from 1859-1864, ... 560
" individual interest in Cornwall ore mine, ... 569
" succession of " " " 563,567
" total production Cornwall ore, 1740-1885, ... 562
" elevations, Allegheny county, ... 142
" " prominent points anthracite region, ... 281
" " " " Bernice coal basin, ... 464

Page.
Table, elevations, prominent points, Mine Sheet, No. III, ... 374
" " " " " " IV, ... 376
" " " " " " V, ... 378–381
" " " " " " VI, ... 382
" " " " " " VII, ... 388–390
" " " " " " VIII, ... 393–397
" lengths of arc of meridian, ... 700
" " " " the parallel, ... 700
" location sections, in anthracite region, ... 291–293
" number and thickness of beds at Greenwood colliery, ... 291
" production individual coal-fields and percentage for 1883 and 1884, 331
" relative areas of anthracite coal fields, ... 277
" " importance of anthracite counties, ... 276
" sizes mesh used to produce varieties of coal, ... 317
" thickness Pottsville conglomerate, different localities, ... 294
" " Red Ash bed, Mine Sheet, No. VI, ... 382
" " strata between Mammoth and Buck Mountain beds, . . 296
" " strata deposited during the geological periods and epochs, 287
" water and rock pressures, ... 658
Tamaqua, coal-beds originally named from A to T, ... 328
" original Survey plan with reference to, ... 325
Tarentum district contributing gas to Pittsburgh, ... 38
" gas field, developments in, ... 37
" horizons furnishing gas at. 10
" supplied with gas from Bull Creek field, ... 38
Taylor, analyses of Penna. anthracites by, ... 310
Tellina balthica, shell found in marine sand in France, ... 117
Temperanceville, ... 163
Templeman's knob, Cornwall, ... 495
Theories for locating oil wells, ... 74
" of occurrence of natural-gas, ... 50
" of oil and gas, ... 42
Third sand, character of oil from, ... 63
" confusion in naming, ... 66
" possibly originally unbroken from Tidioute to St. Joe, ... 71
" of Oil creek, wrongly named, ... 62
" at Triumph, different names of, ... 64
" " thickest yet found in the country, ... 64
"Thomas Clark Survey," Cornwall, ... 550, 564
Thomas, John, Waynesburg synclinal, ... 201
Thomaston colliery, analysis of coal and ash from, ... 323
Thompson gas well, Carbon Center, ... 34
Thompson, Heber S., ... 342
Thorn creek, generally known as the Phenomenal district, ... 22
" district, history foreshadowed by Armstrong well, No. 2, . . 23
" " horizons of, ... 8
" oil-field, total output of, ... 25
" gas rock, Murraysville wells. 10
" oil-sand, Mt. Nebo well, ... 25
" " oil from wells near Rochester not from, ... 26
" pool, oil from Venango-Butler sand, ... 22

Page.
Thorn creek pool, statistics of production, ... 24
" " rocket-like career of, ... 1
Tinklepaugh creek, pot-hole situated on, ... 619
Tipton Run Coal Co., Pocono coal-beds opened on lands of, ... 250
" " openings Blair county, report on, ... 250
" " coals, report on fuel value of, ... 266
" sections taken near, ... 256
Titaniferous iron ore belt, North Carolina, ... 579
Tittmann, O. H., extension of triangulation by, ... 695
Toby's creek, Black Diamond shaft in old bed of, ... 644
" eddy at Kingston, buried valley at 639
Tomlinson, John, "Dopplerite" described by, ... 648
Tom's creek, West Virginia, Pocono coal mined at, ... 254
Topography of anthracite region, ... 280
Topographical map, Bernice coal-field, ... 463
Topton triangulation station, geographical position of, ... 699, 703
Trap dykes, Connecticut River Valley, ... 503
" " Lancaster county, ... 503
" and limestone peak, relative positions of, ... 502
" outburst of, at Cornwall, a consequence of fault, ... 496
" responsible for magnetic quality of Cornwall ore, ... 530
" rock, Cornwall, description of, ... 497
Trenton limestone beds, Great Valley, ... 545
Trevorton, survey extended four miles west of, ... 346
" or North Franklin white ash coal, ... 305
Triangulation, geodetic, of Pennsylvania, ... 681
" instruments used on Coast and Geodetic Survey, ... 688
" measurement of base lines, ... 687
" methods of geodetic, ... 686
" " of observation in, ... 688
" " of taking angles, ... 691
" nature of a geodetic, ... 681
" use of, ... 684
" survey of Pennsylvania, objects of, ... 682
" " " Stations in horse shoe chain, . . . 701
" " " progress of, ... 693
" " " results of angle measurements in, . 692
" on United States Coast and Geodetic Survey, ... 686
Triassic limestone beds quarried in Adams county, ... 569
Trilobites, Wilkes Barre fossil collection, fragments of, ... 451
Tripp farm bore-hole, thickness of "wash" in, ... 630, 644
Trucks & Parker, analysis washed kaolin, ... 587
Tuna Valley oil-wells depth of, ... 79
Tunkhannock mountain, ... 459
Tunnel opening, Tipton run, ... 261
Turkey run colliery, analysis of coal and ash from, ... 322
" " " Mammoth bed, ... 315
Twin coal-bed, Northern Field, where mined, ... 368, 372

U.

Page.
United States Geological Survey, ... 42
Union Iron Mills, use of natural-gas at, ... 667
Union township, Washington county, elevations, ... 150
Uniontown coal-bed, ... 172
" " horizon of, ... 206
" " near Round Hill church, ... 194
United States Coast and Geodetic Survey, triangulation by, ... 681
Undulations of the Wyoming-Lackawanna basin, ... 399, 404
Upper Baltimore coal-bed, thickness of, ... 392
" " " where mined, ... 368, 372
" Devonian strata, oil and gas wells in, ... 46
" Lehigh Coal Field, extent of, ... 275
" productive coal measures, ... 171
" " " " Horner & Roberts mine, ... 208
" " " " limestones, ... 437
" " " " section of, ... 172
" St. Clair township, Allegheny county, elevations, ... 144
Utilization of anthracite waste, ... 299

V.

Valentine, Mr., analysis of Cornwall ore, ... 534
Variable deposits remarks on, ... 70
Vegetable origin of coal, ... 95
Venango oil-sands. Brady's Bend, dip of rocks, ... 58
" " Bradford, McKean county, ... 79
" " Warren county, ... 79
" group, Northern Venango, Crawford, and Warren counties, . . 34
" " in Warren and Forest districts, ... 16
" county, Red Valley oil-pool in. 1
" district, many large gas wells in, ... 33
Venango-Butler district, ... 19
" " group, in Pittsburgh and Washington counties, ... 4
" " " extensive operations in white sands of, ... 1
" " " in Buchanan wells, ... 7
" " " Thorn Creek district, ... 9
" " " Tidioute to Washington, ... 4
" " " Warren-Forest district wells, ... 17
" " " furnishing gas for Pittsburgh wells, ... 38
" " " Gordon well, ... 11
" " " in McGuigan well, ... 40
" " " sand beds in, ... 48
" " " sections Nos. 1, 2, and 3, ... 7
" " " supply gas wells in S. W. Pa., ... 4
" " First sand same as Pittsburgh salt water rock, ... 9
" " oil-sand, Cogley Run pool, ... 22
" " " " Red Valley pool, ... 22
" " " " Thorn Creek pool, ... 22
" and Clarion belts, variability of oil-sands between, ... 25
Versailles twp., Washington co., little Pittsburgh coal left in, ... 161

Page.
Vesuvianite found at Cornwall, ... 547
Virginia and North Carolina, ... 578

W.

Wad found at Cornwall, ... 547
Wadesville colliery, analysis of coal and ash from, ... 323
Wainwright. J., miscellaneous levels furnished by, ... 155
Wales, gradual transition of a bituminous to an anthracite bed in, ... 319
Wall, A. C. & I., lands of, ... 207
Wall & Applegate land, outcrop of Pittsburgh coal-bed on, ... 211
Walker mine, ... 211
Walker's, State of Delaware. gravels at, ... 573
Wanamie slope, No. 18, anticlinal and basins, ... 418
" No, 18, colliery, elevations, ... 374
" " " " operator and beds worked at, ... 371
" " 19, " " " " " 371
Wardwell oil-pool, production of, ... 19
" " pool rise and fall, ... 1
Warrantee lines on maps of Northern Coal Field, ... 361
Warren, Bradford co., geographical position of, ... 706
" outcrop of Venango oil-sands, ... 79
" product of Sheffield gas-pool piped to , ... 33
" co., Kinzua oil-pool in, ... 1
" district, production of, ... 19
" group, discovery of a rich gas deposit in a sand belonging to the. 34
" " gas found in Cranberry twp., Venango co., ... 4
" oil rocks found in Warren and Forest district wells, ... 17
" and Forest cos., oil-pools in, ... 1
" " " district, ... 16
" " McKean cos., oil fields of, ... 78
Warrior Run colliery, elevations, ... 376
" " " four coal-beds worked at, ... 375
" " " operator and beds worked at, ... 371
" " Mine Sheet, No. IV, ... 375
Warwick mines, ... 511
Washington, gas developments near, ... 40
" horizons furnishing gas at, ... 10
" axis, ... 167
" " named from Washington borough, ... 162
" or Brady's Bend anticlinal, ... 162
" co., elevations, ... 151, 152, 153
" " gas wells supplied from Venango-Butler group, ... 4
" " Washington pool in, ... 1
" twp., Fayette co., elevations, ... 156
" Naval observatory, geographical position of, ... 707
Watson well, Johnsonburg station, Elk co., large volume of gas from, . 31, 32
" " Titusville, cuts oldest rocks, ... 7
Waynesburg, ... 165
" anticlinal, ... 165
" coal-bed, Harmony school-house, ... 194

Page.
Waynesburg coal not found on Perry's mill run. 206
" limestone, ... 206
" synclinal, ... 168,169
"Wealden deposit," 583
Wedell's, Peter, pit, coal opened, ... 186
Weld, H. T., North Savage Firebrick Co's. mine on land of, ... 239
Well records, necessity of preserving, ... 77
Welsh, Palmer & Maxwell, owners North Savage Firebrick Mine, ... 239
Weller, J. P., warrantee lines from atlas of Luzerne co., by, ... 362
Wells. Bard, charge of party in Western Middle Coal-Field, ... 334
" " section in Pottsville basin, ... 330
Wellsville-gas from Allegheny oil district piped to, ... 31
Wellersburg bore hole, section of, ... 231
" or Southampton coal-basin, ... 228
" section made to verify Gladden's run section, ... 229
" " near, by Professor James Hall, ... 229
" " " by Henry K. Strong, ... 229
" surface section, Barren Measures, ... 230
Wenona mine, ... 213
Weser and Elbe rivers bogs at mouth of, ... 115
West End, No. 1, colliery, operator and bed worked at. 372
West Liberty, ... 163
West Penn railroad, elevations along. 141
West Shenandoah colliery, analysis of coal and ash from, ... 322
West Virginia, prospecting for oil and gas in, ... 2
Western Middle Coal-Field, survey of, ... 333
" " no columnar section sheets published, . . . 335
" " extent of, ... 275
" " inconsistencies in naming strata, ... 336
" " Mine Sheet, No. I, ... 338
" " " plan of colliery examinations, . . 337
" " published sheets. 334, 335
" " survey, commencement of, ... 333
" " coal-bed areas under properties in, ... 337
" " sections of, ... 291, 292, 293
" " topographical map of, ... 345
Western Northern Coal-Field, extent of, ... 276
" Pennsylvania, weight of super-rocks in, ... 659
Westmoreland Coal Company, character of coal shipped by, ... 176
" county, elevations of, ... 154, 155
Westinghouse, No. 1 well, ... 40
Wethered, Professor, reseaches on origin of coal by, ... 99
Wetmore, heat and light supplied by well near, ... 32
Wettengill's country pit, ... 164
Wharton bed, analysis, ... 313
Wheatly, C. M., copper ore mined at Cornwall under agreement with, . . 546
Wheeling division B. & O. R. R., elevations along, ... 137
Whelpley, James D., explanation of hooking of trap by, ... 504
Whiskey run, ... 164
White, C. A., granite surfaces of Minnesota, ... 580
White clay walls in railroad cuts, Grey's Ferry, ... 584

Page.
White Haven, Luzerne county, line of glacial epoch at, ... 615
" Horse triangulation station, geographical position of, ... 689, 702
White & Hazzard, first use of coal in manufacturing iron, ... 278
White Hill colliery near Edinburgh, spores, etc., in splint coal at, ... 100
White, Professor I. C., ... 178, 487
" " " Ancient Valley traced by, ... 637
" " " report on Wellersburg basin, ... 229
White sand, Warren and Forest counties, ... 3
Wilcox district, pressure of gas in, ... 39
" gas pool, Bradford supplied from, ... 31
" well No. 1, record of, ... 663
" wells, oil produced from the Bradford sand, ... 31
Wild Cat Hollow, ... 188
" wells, Potter county, ... 82
Wiley's run, Pittsburgh coal opened, ... 186
Wilhelm, A., ... 551
Wilkensburg village, ... 165
Wilkes Barre basin, elevations, ... 285
" court-house, latitude and longitude of, ... 361
" fossils, report on, ... 450
" " representative carboniferous species, ... 450
" limestone beds, outcrops of, ... 439, 443
" Mine Sheet, No. VIII, ... 390
" Pottsville conglomerate, thickness of, ... 289
" collieries, waste in preparing Red Ash bed coal, ... 299
" geographical position of, ... 705, 706
Wilkins twp., Allegheny county, elevations, ... 143
Williams, Albert, Jr., fallacies regarding precious metal deposits, ... 42
" G. M., report on Nanticoke disaster, ... 628
" A. W., analysis of gas well incrustation by, ... 679
" T. J., assistant in Northern Coal-field, ... 354
" station, fire-clay bed opened near, ... 246
Willow Grove station, geographical position of, ... 704
Williamson, researches on origin of coal, ... 99
Wills creek, rock exposures made by, ... 239
Winchell, N. H., granite surfaces of Minnesota, ... 580
Winslow, Arthur, field work in Eastern Middle Coal-field, ... 347
" " Pottsville conglomerate, Ashley planes measured by, . 393
Winterstown triangulation station, geographical position of, ... 695, 705
Wire-rope haulage, Cornell & Werling mines, ... 189
" " Gumpert, Hewing & Co. mine, ... 185
Wisconsin ore-bearing clays, ... 591
Wolf Creek well, no market for gas from, ... 35
Womelsdorf, A. J., topographical map Western Middle Coal-field atlas by, 345
" gentle dips in strata along R. R. to, ... 541
" triangulation station, geographical position of, ... 694, 702
Woods run, ... 163
Woodside, geographical position of, ... 705
Woodward, Mr., superintendent of Bernice mines, ... 480
" farm bore-holes, depth of, ... 646
" " " thickness of wash in, ... 680

Page.
Wootten, J. E, use of waste coal, ... 299
Wright, Harrison, collection of fossils made by, ... 439
Wyooff, Mr., Redstone coal opened by, ... 193
Wyoming Buried Valley, between Pittston and Kingston, description, . . 637
Wyoming colliery, elevations, ... 388,397
" " operator and beds worked, ... 372
" " workings of, ... 639
" and Enterprise collieries, Five-Foot coal-bed worked at, . . . 387
" Historical and Geological Society, ... 439
" " " " " fossils, property of, ... 451
" and Lackawanna coal-field, extent of, ... 276
" -Lackawanna Valley, glacier once covered, ... 616
" " " thickness of ice in Ice Age, ... 615
" overturn, ... 400
" red ash coal, not referred to in J. S. Harris' report, ... 305
" shaft anticlinal, ... 408
" Valley, descriptions of basins and anticlinals, ... 404
" " limestone beds, report on, ... 437
" reconnoissance made in early part of November, 1880, . . 358
Yard triangulation station, geographical position of, ... 697,704
Youghiogheny, Coal Hollow Co.'s mines, ... 176
" railroad, elevations along, ... 181

Z.

Ziegman, analysis of peat material by, ... 117